

# **EXHIBIT 1**

U 8079874



# THE UNITED STATES OF AMERICA

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**U.S. PATENT: 9,463,289**

**ISSUE DATE: *October 11, 2016***

**By Authority of the**

**Under Secretary of Commerce for Intellectual Property  
and Director of the United States Patent and Trademark Office**



  
**P. R. GRANT**  
Certifying Officer

(12) **United States Patent**  
**Walsh et al.**(10) **Patent No.:** **US 9,463,289 B2**(45) **Date of Patent:** **Oct. 11, 2016**(54) **DOSE COUNTERS FOR INHALERS, INHALERS AND METHODS OF ASSEMBLY THEREOF**(71) Applicants: **IVAX PHARMACEUTICALS IRELAND**, Utrecht (NL); **NORTON WATERFORD**, Utrecht (NL); **TEVA PHARMACEUTICALS IRELAND**, Utrecht (NL)(72) Inventors: **Declan Walsh**, County Kilkenny (IE); **Derek Fenlon**, County Wexford (IE); **Simon Kaar**, County Cork (IE); **Jan Geert Hazenberg**, County Kilkenny (IE); **Daniel Buck**, County Waterford (IE); **Paul Clancy**, Waterford (IE); **Robert Charles Uschold**, Leominster, MA (US); **Jeffrey A. Karg**, Hopkinton, MA (US)(73) Assignees: **IVAX Pharmaceuticals Ireland**, Waterford (IE); **Norton (Waterford) Limited**, Waterford (IE); **Teva Pharmaceuticals Ireland**, Waterford (IE)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/103,324**(22) Filed: **Dec. 11, 2013**(65) **Prior Publication Data**

US 2014/0096769 A1 Apr. 10, 2014

**Related U.S. Application Data**

(62) Division of application No. 13/110,532, filed on May 18, 2011, now Pat. No. 8,978,966.

(60) Provisional application No. 61/345,763, filed on May 18, 2010, provisional application No. 61/417,659, filed on Nov. 29, 2010.

(51) **Int. Cl.****G06M 1/06** (2006.01)**A61M 11/00** (2006.01)

(Continued)

(52) **U.S. Cl.**CPC ..... **A61M 15/0071** (2014.02); **A61M 11/00** (2013.01); **A61M 15/009** (2013.01);  
(Continued)(58) **Field of Classification Search**USPC ..... 235/8, 103; 128/200.23  
See application file for complete search history.(56) **References Cited****U.S. PATENT DOCUMENTS**

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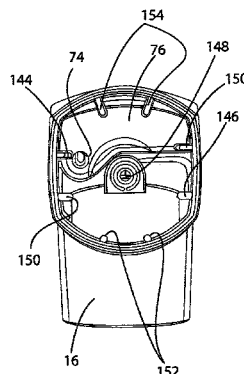
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*Primary Examiner* — Daniel Hess(74) *Attorney, Agent, or Firm* — RatnerPrestia(57) **ABSTRACT**

A manually operated metered dose inhaler includes a dose counter chamber including a dose display tape driven by a ratchet wheel which is driven in turn by an actuator pawl actuated by movement of a canister, the tape unwinding from a stock bobbin during use of the inhaler, a rotation regulator being provided for the stock bobbin and including a wavelike engagement surface with concavities which engage against control elements in the form of protrusions on resilient forks of a split pin thereby permitting incremental unwinding of the stock bobbin yet resisting excessive rotation if the inhaler is dropped onto a hard surface.

**10 Claims, 17 Drawing Sheets**

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- (51) **Int. Cl.**  
**A61M 15/00** (2006.01)  
**G06M 1/24** (2006.01)
- (52) **U.S. Cl.**  
CPC ..... **A61M15/0025** (2014.02); **A61M 15/0026**  
(2014.02); **A61M 15/0065** (2013.01); **A61M**  
**15/0078** (2014.02); **G06M 1/246** (2013.01);  
**A61M 2202/064** (2013.01); **A61M 2205/6063**  
(2013.01); **A61M 2207/00** (2013.01); **A61M**  
**2207/10** (2013.01); **Y10T 29/49** (2015.01);  
**Y10T 29/49764** (2015.01); **Y10T 29/49826**  
(2015.01)
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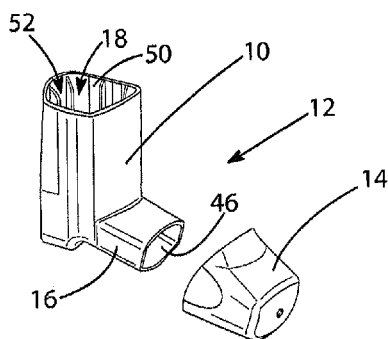


FIG. 1

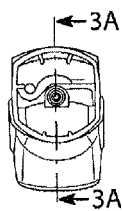


FIG. 2

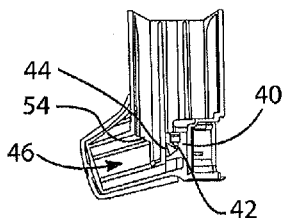


FIG. 3A

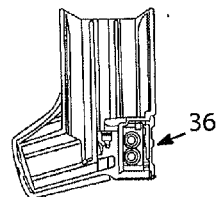


FIG. 3B

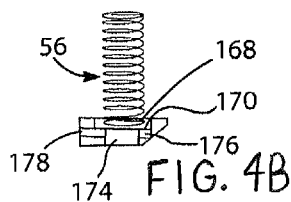


FIG. 4B

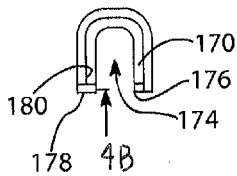


FIG. 4C

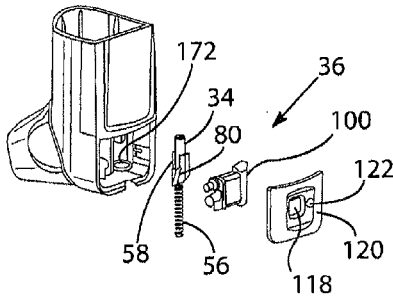


FIG. 4A

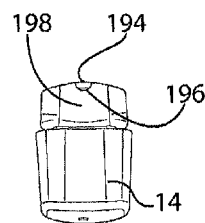


FIG. 5

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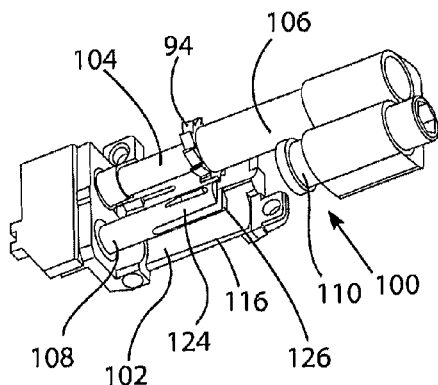


FIG. 6A

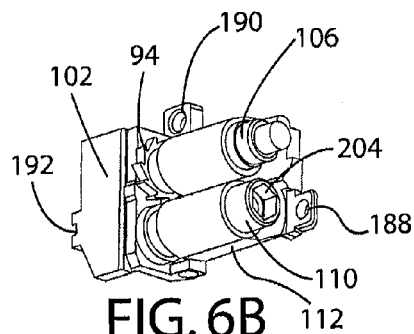


FIG. 6B

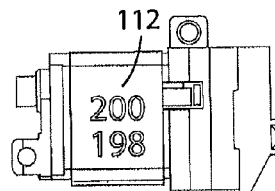


FIG. 6C

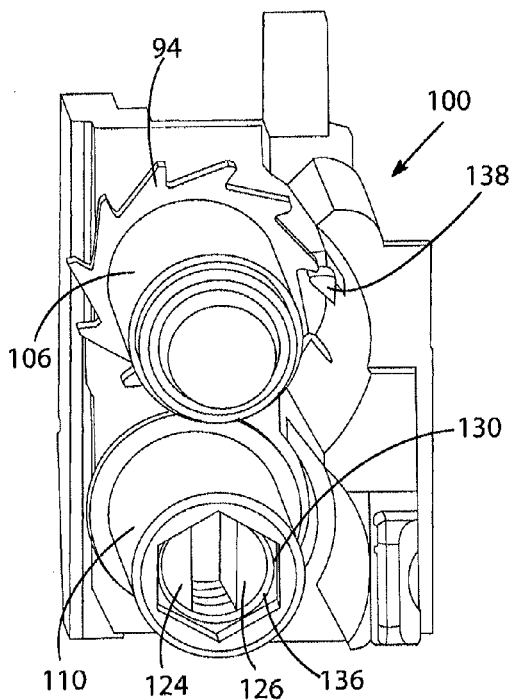


FIG. 6D

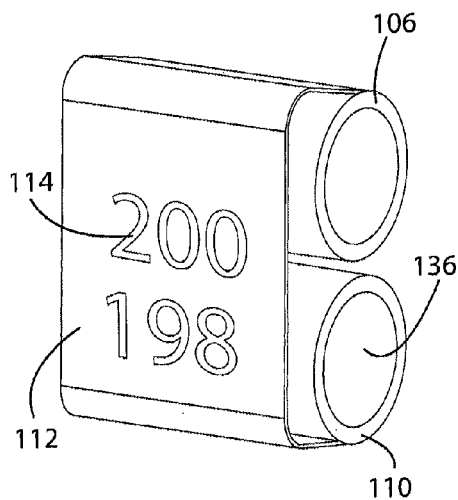


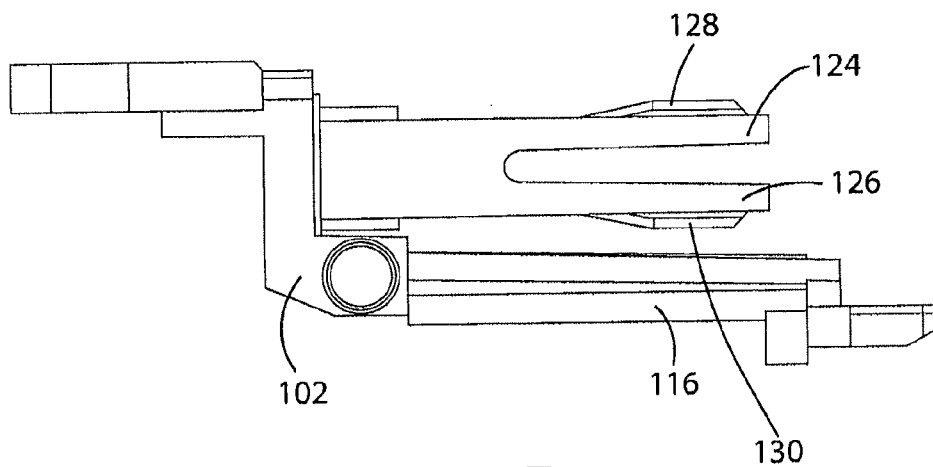
FIG. 6E

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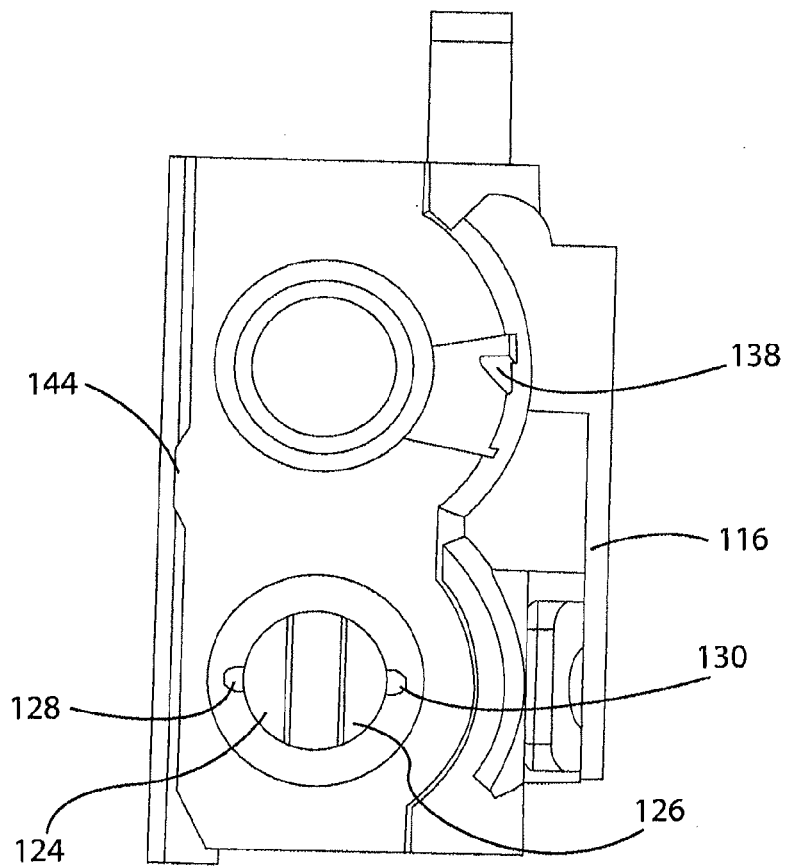
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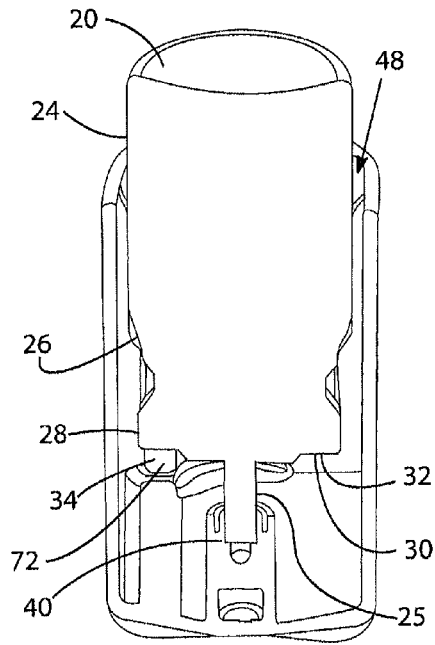
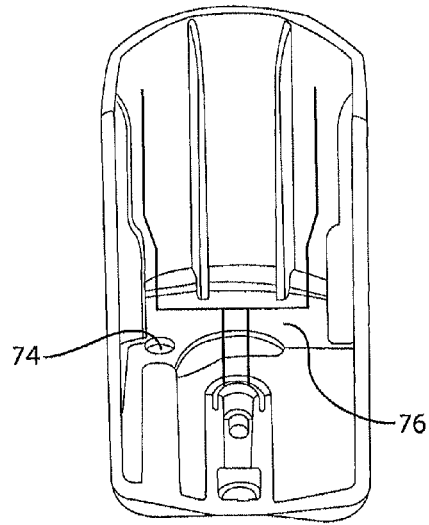
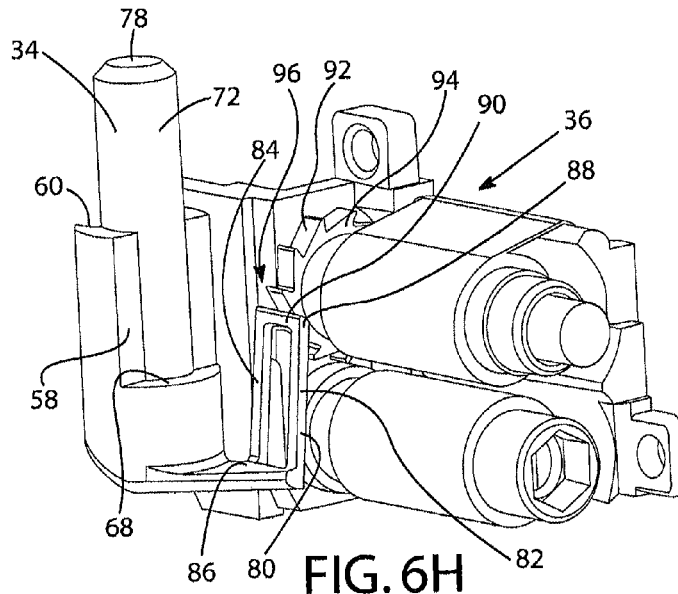
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**FIG. 6F**



**FIG. 6G**

**U.S. Patent****Oct. 11, 2016****Sheet 4 of 17****US 9,463,289 B2****FIG. 7A****FIG. 7B****FIG. 6H**

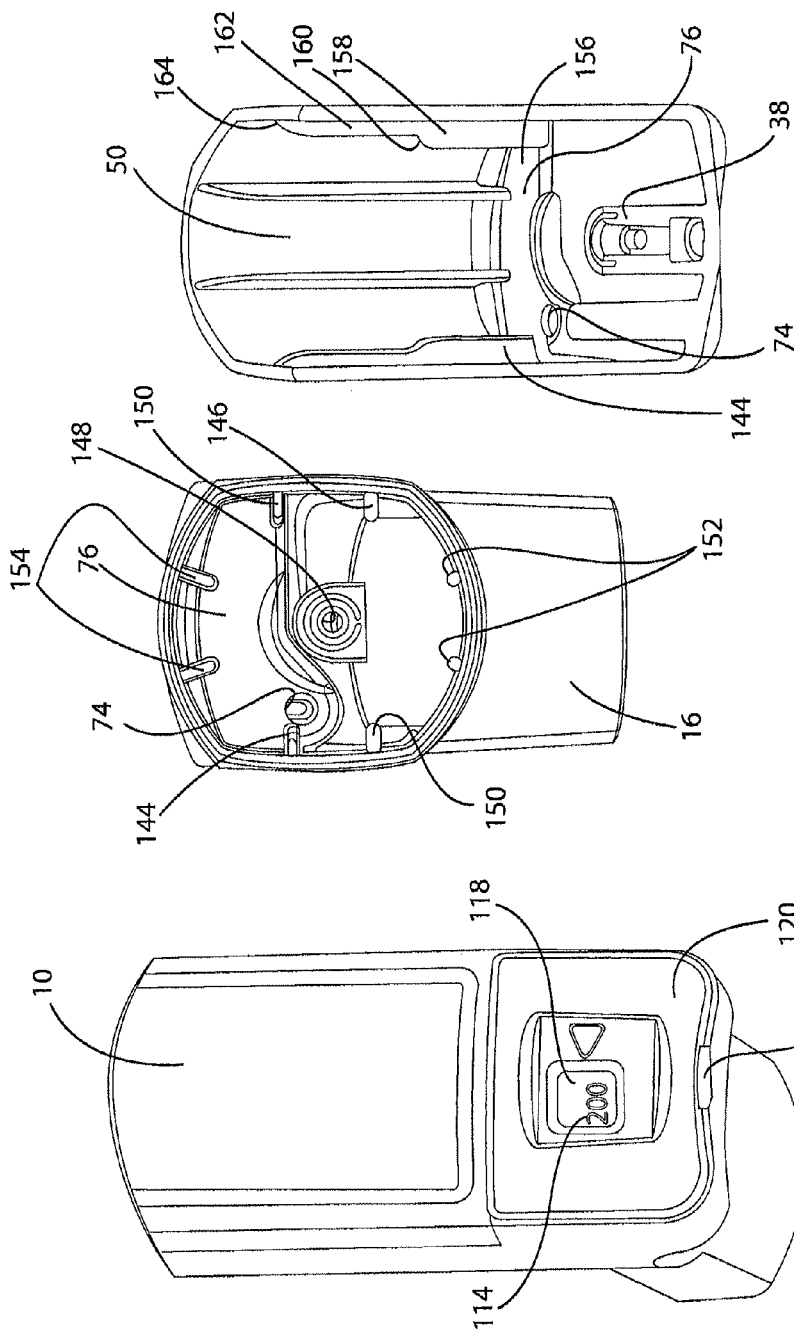


FIG. 7C

FIG. 7D

FIG. 8D



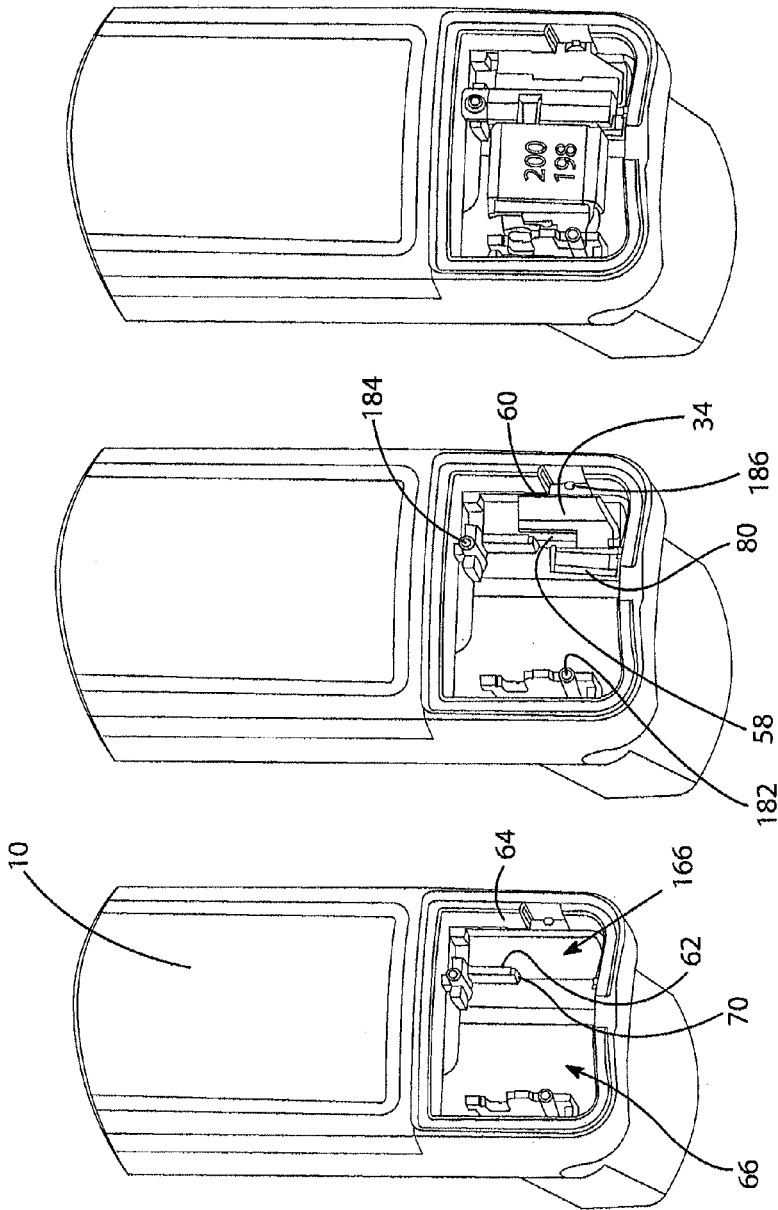


FIG. 8C

FIG. 8B

FIG. 8A



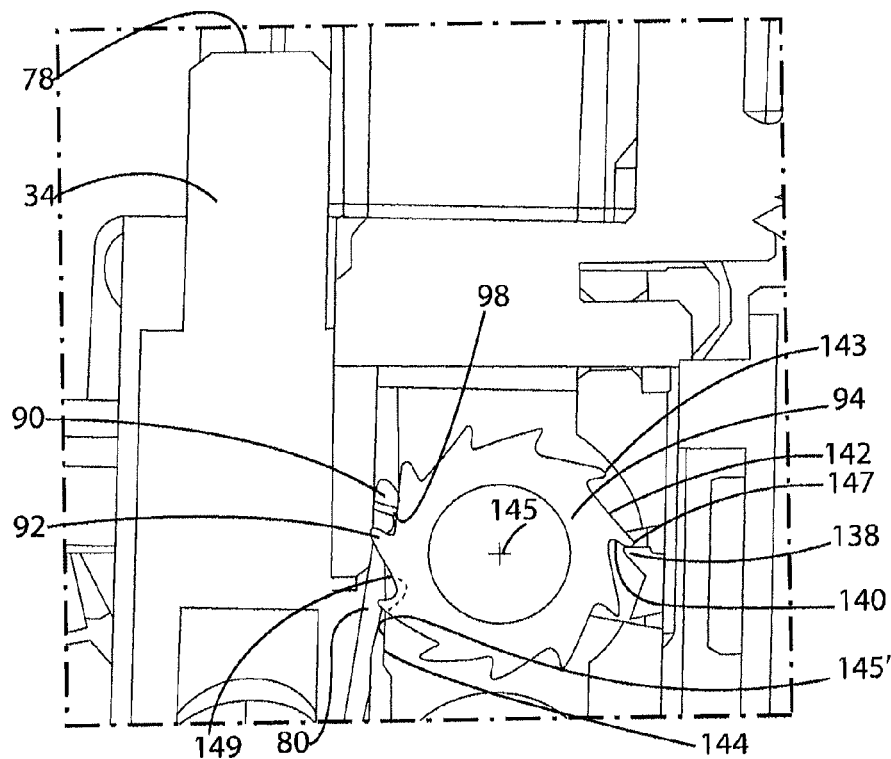
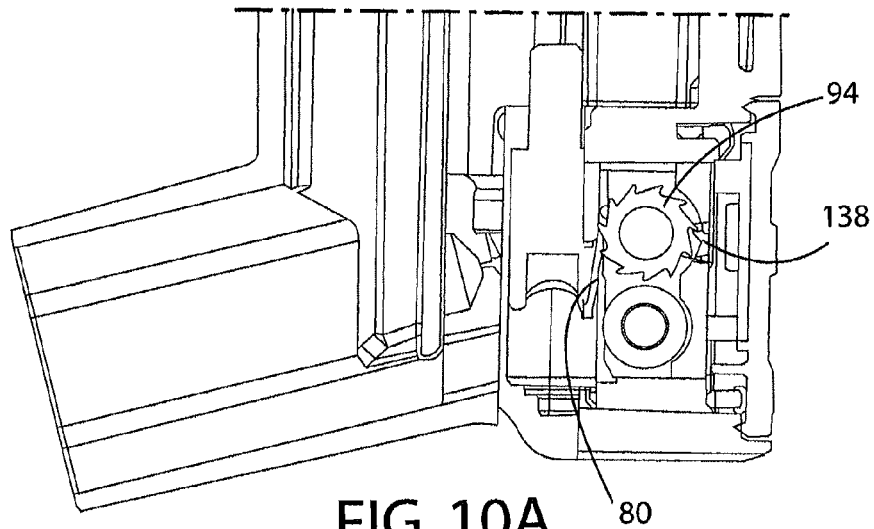
**FIG. 9**

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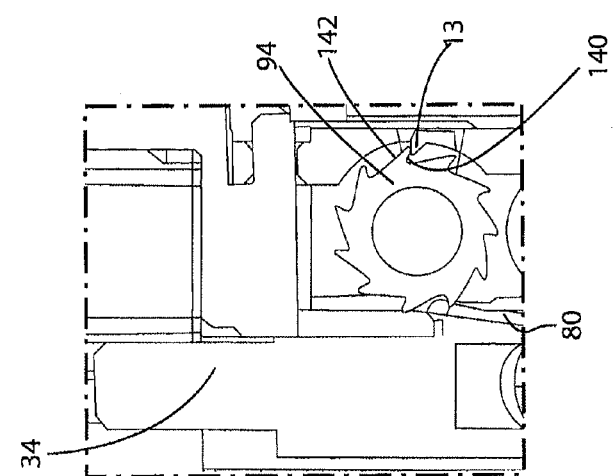


FIG. 10E

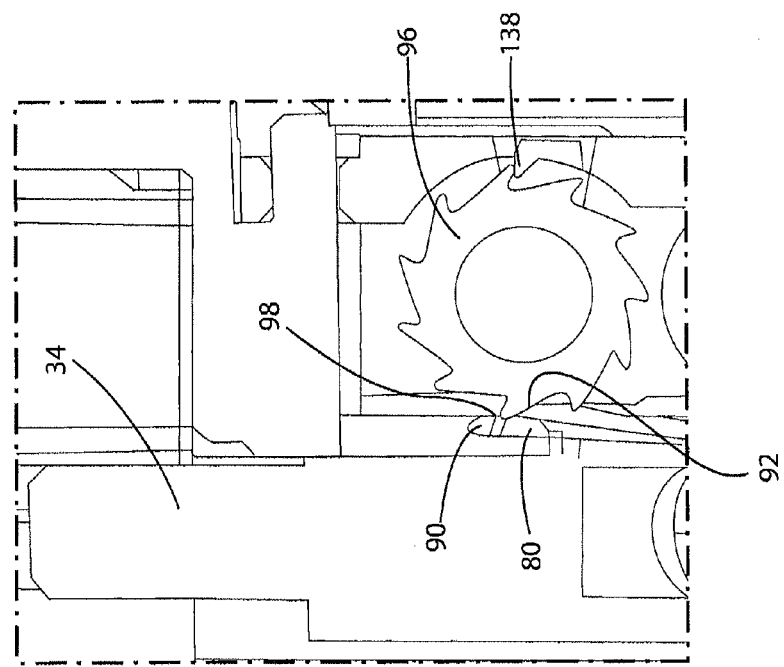


FIG. 10C

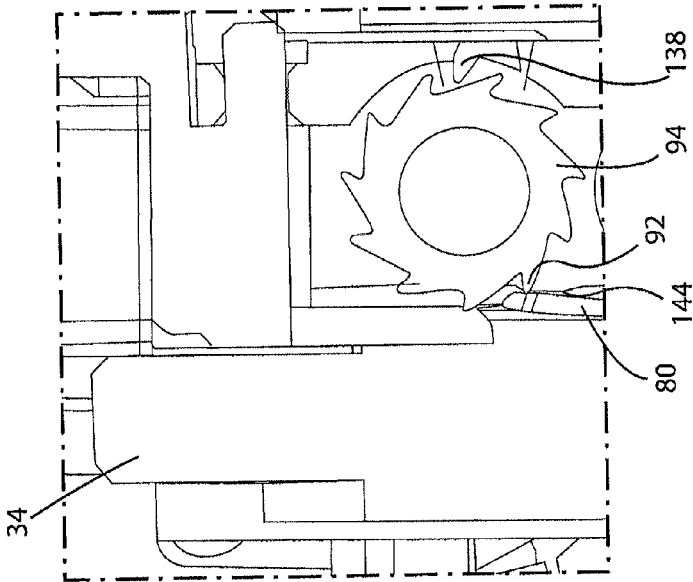


FIG. 10F

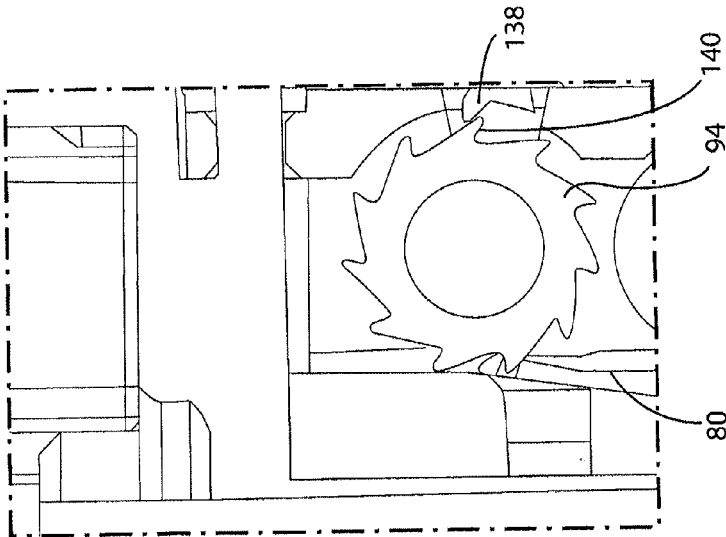


FIG. 10D



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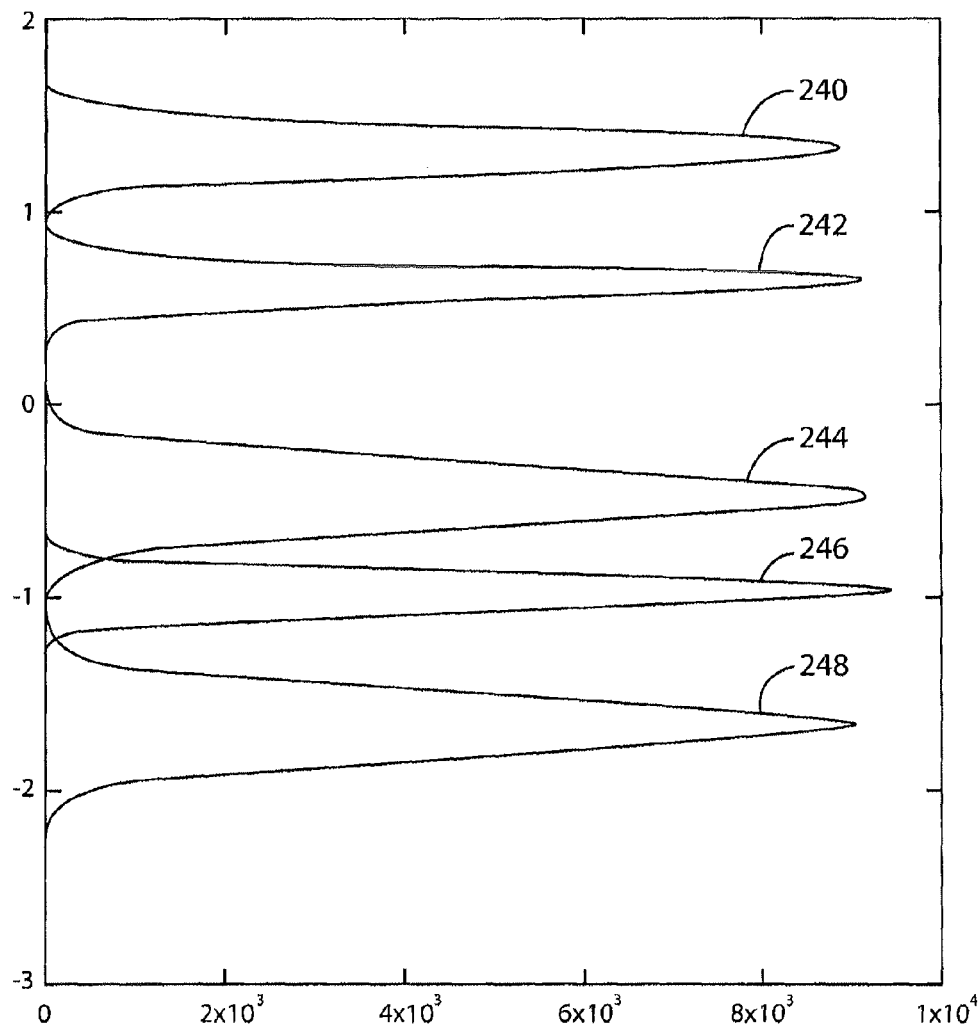


FIG. 11

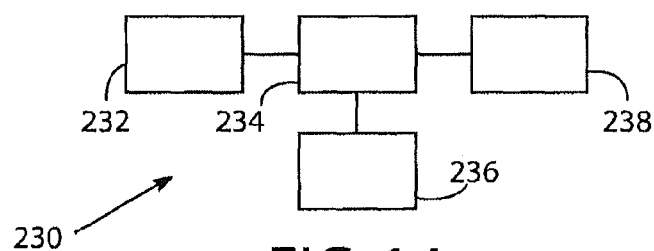


FIG. 14

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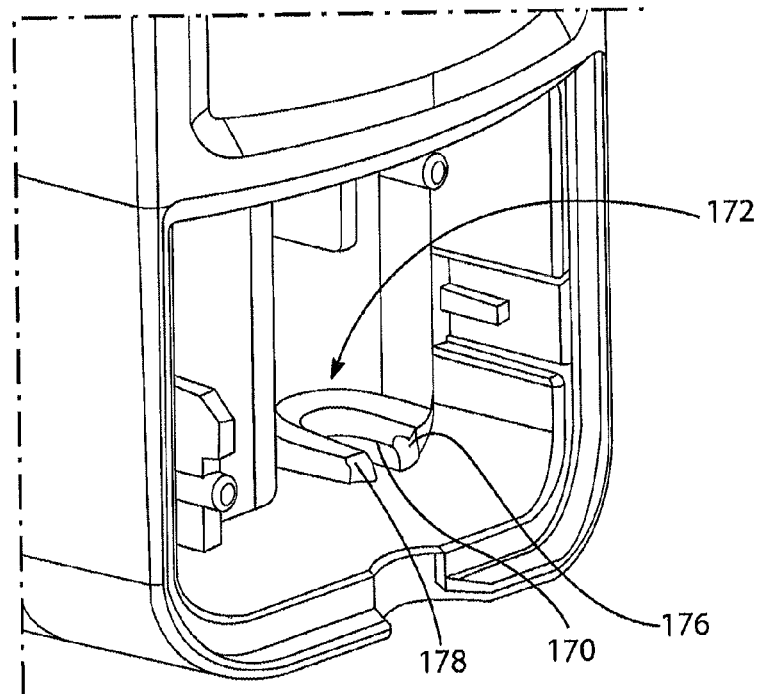


FIG. 12

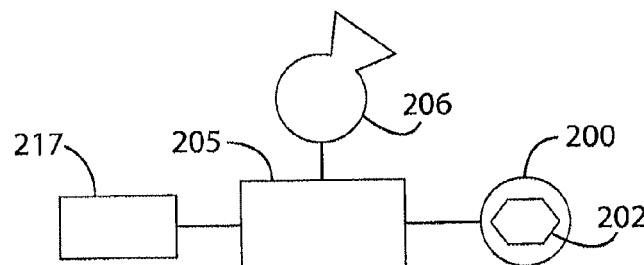
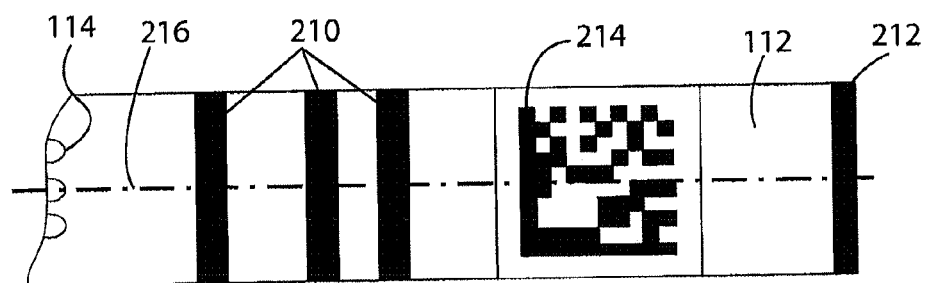


FIG. 13

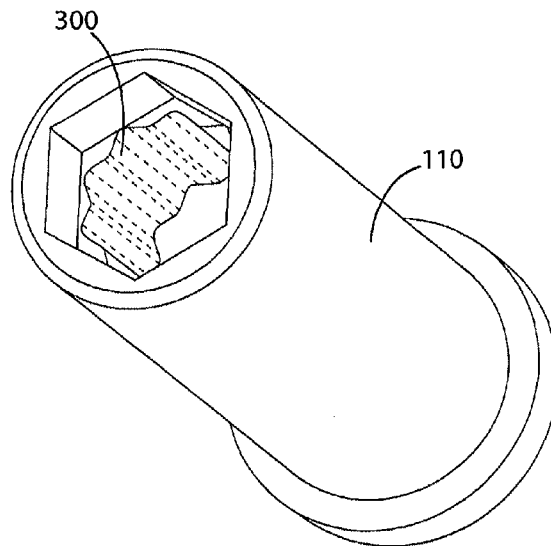


FIG. 15

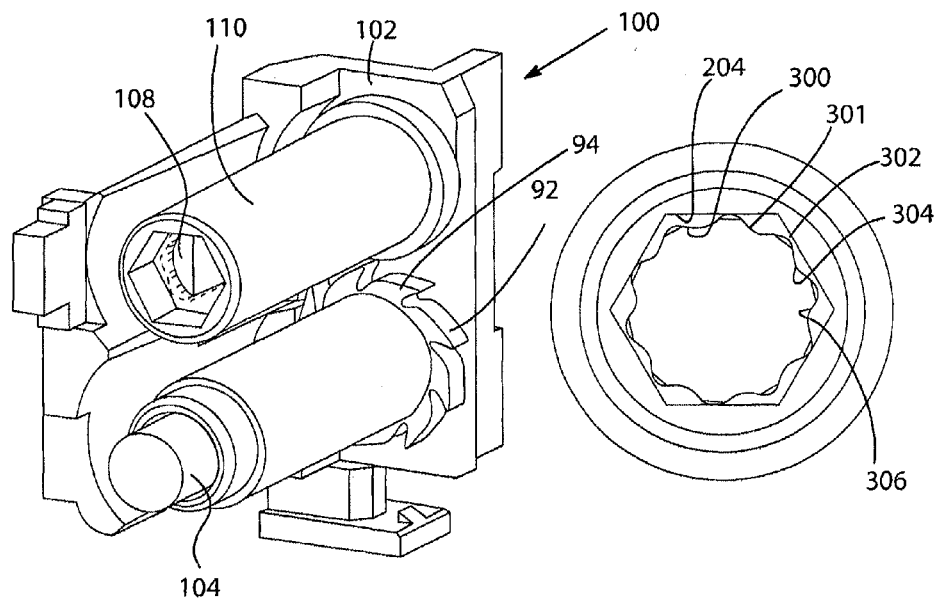


FIG. 20

FIG. 16

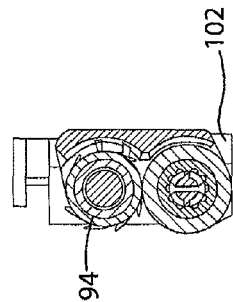


FIG. 19A

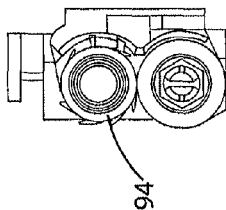


FIG. 19B

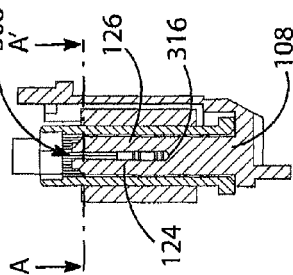


FIG. 19C

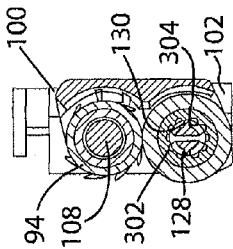


FIG. 18A

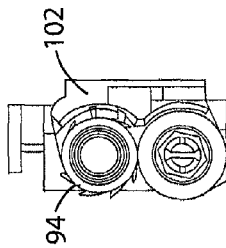


FIG. 18B

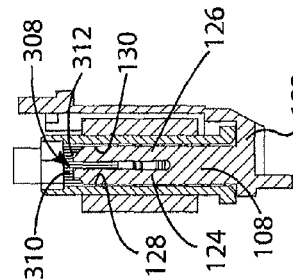


FIG. 18C

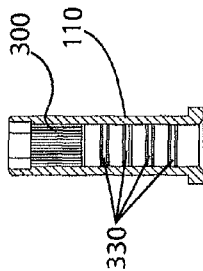
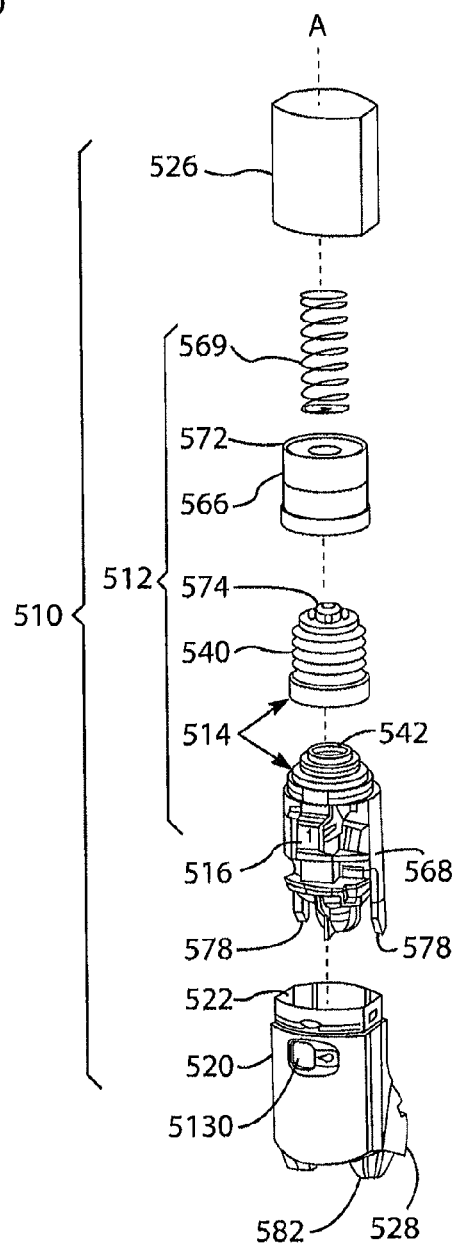
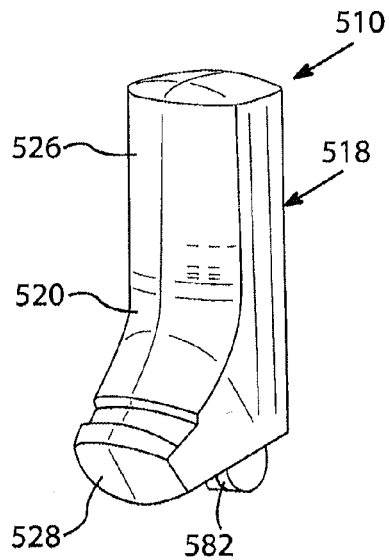


FIG. 17





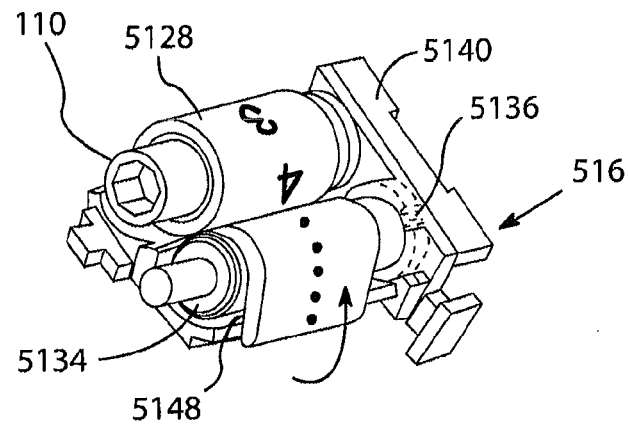


FIG. 23

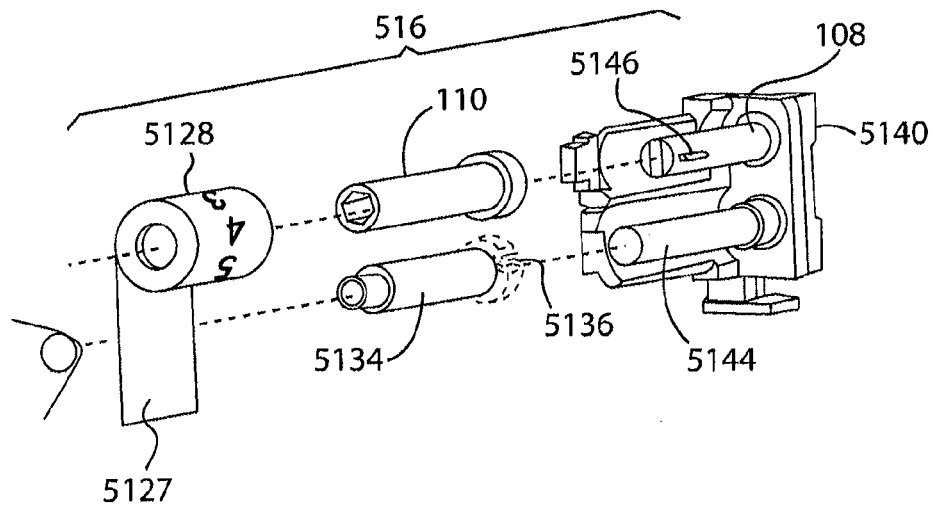
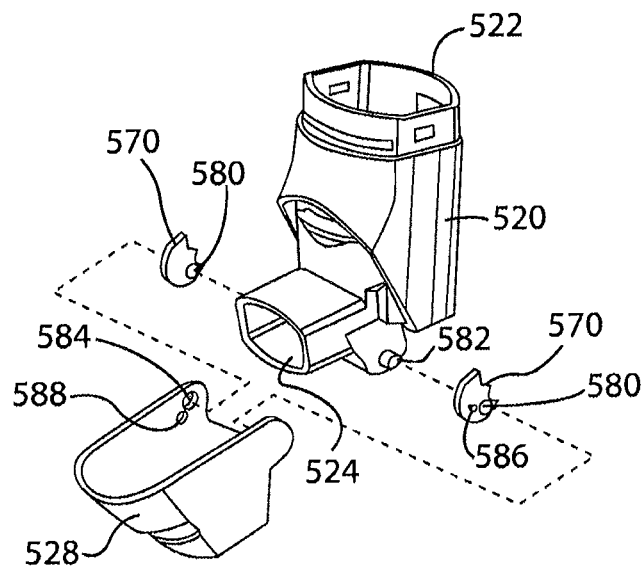
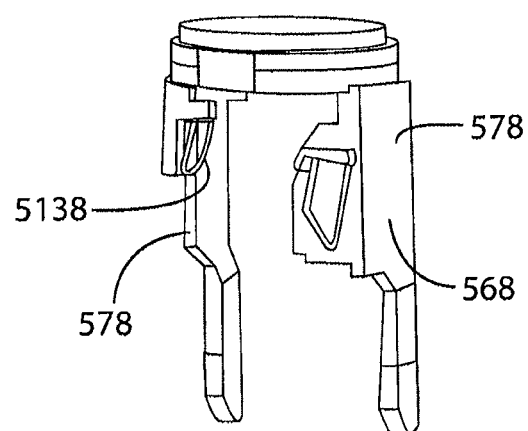


FIG. 24

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**US 9,463,289 B2****FIG. 25****FIG. 26**

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1

**DOSE COUNTERS FOR INHALERS,  
INHALERS AND METHODS OF ASSEMBLY  
THEREOF**

**CROSS-REFERENCE TO RELATED  
APPLICATIONS**

This patent application is a divisional patent application of U.S. Non-Provisional patent application Ser. No. 13/110,532, filed May 18, 2011, which claims priority to U.S. Provisional Patent Application No. 61/345,763, filed May 18, 2010, and U.S. Provisional Patent Application No. 61/417,659, filed Nov. 29, 2010, each of which is incorporated herein by reference in its entirety for all purposes.

**FIELD OF THE INVENTION**

The present invention relates to dose counters for inhalers, inhalers and methods of assembly thereof. The invention is particularly applicable to metered dose inhalers including dry power medicament inhalers, breath actuated inhalers and manually operated metered dose medicament inhalers.

**BACKGROUND OF THE INVENTION**

Metered dose inhalers can comprise a medicament-containing pressurised canister containing a mixture of active drug and propellant. Such canisters are usually formed from a deep-drawn aluminium cup having a crimped lid which carries a metering valve assembly. The metering valve assembly is provided with a protruding valve stem which, in use is inserted as a push fit into a stem block in an actuator body of an inhaler having a drug delivery outlet. In order to actuate a manually operable inhaler, the user applies by hand a compressive force to a closed end of the canister and the internal components of the metering valve assembly are spring loaded so that a compressive force of approximately 15 to 30N is required to activate the device in some typical circumstances.

In response to this compressive force the canister moves axially with respect to the valve stem and the axial movement is sufficient to actuate the metering valve and cause a metered quantity of the drug and the propellant to be expelled through the valve stem. This is then released into a mouthpiece of the inhaler via a nozzle in the stem block, such that a user inhaling through the outlet of the inhaler will receive a dose of the drug.

A drawback of self-administration from an inhaler is that it is difficult to determine how much active drug and/or propellant are left in the inhaler, if any, especially of the active drug and this is potentially hazardous for the user since dosing becomes unreliable and backup devices not always available.

Inhalers incorporating dose counters have therefore become known.

WO 98/280733 discloses an inhaler having a ratchet mechanism for driving a tape drive dose counter. A shaft onto which tape is wound has a friction clutch or spring for restraining the shaft against reverse rotation.

EP-A-1486227 discloses an inhaler for dry powered medicament having a ratchet mechanism for a tape dose counter which is operated when a mouthpiece of the inhaler is closed. Due to the way in which the mouthpiece is opened and closed, and actuation pawl of the device which is mounted on a yoke, travels a known long stroke of consistent length as the mouthpiece is opened and closed.

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WO 2008/119552 discloses a metered-dose inhaler which is suitable for breath-operated applications and operates with a known and constant canister stroke length of 3.04 mm+/-0.255 mm. A stock bobbin of the counter, from which a tape is unwound, rotates on a shaft having a split pin intended to hold the stock bobbin taut. However, some dose counters do not keep a particularly reliable count, such as if they are dropped onto a hard surface.

More recently, it has become desirable to improve dose counters further and, in particular, it is felt that it would be useful to provide extremely accurate dose counters for manually-operated canister-type metered dose inhalers. Unfortunately, in these inhalers, it has been found in the course of making the present invention that the stroke length of the canister is to a very large extent controlled on each dose operation by the user, and by hand. Therefore, the stroke length is highly variable and it is found to be extremely difficult to provide a highly reliable dose counter for these applications. The dose counter must not count a dose when the canister has not fired since this might wrongly indicate to the user that a dose has been applied and if done repeatedly the user would throw away the canister or whole device before it is really time to change the device due to the active drug and propellant reaching a set minimum. Additionally, the canister must not fire without the dose counter counting because the user may then apply another dose thinking that the canister has not fired, and if this is done repeatedly the active drug and/or propellant may run out while the user thinks the device is still suitable for use according to the counter. It has also been found to be fairly difficult to assembly some known inhaler devices and the dose counters therefor. Additionally, it is felt desirable to improve upon inhalers by making them easily usable after they have been washed with water.

The present invention aims to alleviate at least to a certain extent one or more of the problems of the prior art.

**SUMMARY OF THE INVENTION**

According to a first aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a counter display arranged to indicate dosage information, a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input, wherein a regulator is provided which is arranged to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

The regulator is advantageous in that it helps prevent unwanted motion of the counter display if the counter is dropped.

According to a further aspect of the present invention, the regulator provides a resistance force of greater than 0.1 N against movement of the counter display. According to still a further aspect of the present invention, the resistance force is greater than 0.3 N. According to yet a further aspect of the present invention, the resistance force is from 0.3 to 0.4 N.

Preferably, the counter comprises a tape.

Preferably, the tape has dose counter indicia displayed thereon. The first station may comprise a region of the dose counter where tape is held which is located before a display location, such as a display window, for the counter indicia.

The first station may comprise a first shaft, the tape being arranged on the first shaft and to unwind therefrom upon movement of the counter display.

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The first shaft may be mounted for rotation relative to a substantially rotationally fixed element of the dose counter.

The regulator may comprise at least one projection which is arranged on one of the first shaft and the substantially rotationally fixed element and to engage incrementally with one or more formations on the other of the first shaft and the substantially rotationally fixed element.

At least two said projections may be provided. Exactly two said projections may be provided.

Each projection may comprise a radiused surface.

The at least one projection may be located on the substantially fixed element which may comprise a fixed shaft which is fixed to a main body of the dose counter, the first shaft being rotationally mounted to the fixed shaft.

Preferably, the fixed shaft has at least two resiliently flexible legs (or forks). Each leg may have at least one said projection formed in an outwardly facing direction thereon, said one or more formations being formed on an inwardly facing engagement surface of the first shaft, said at least one projection being arranged to resiliently engage said one or more formations. Preferably, a series of said formations are provided. An even number of said formations may be provided. Eight to twelve of said formations may be provided. In one embodiment, ten said formations are provided.

Each said formation may comprise a concavity formed on an engagement surface. Each concavity may comprise a radiused surface wall portion which preferably merges on at least one side thereof into a flat wall portion surface. The engagement surface may include a series of said concavities, and convex wall portions of the engagement surface may be formed between each adjacent two said concavities, each said convex wall portion comprising a convex radiused wall portion.

Each convex radiused wall portion of each convex wall portion may be connected by said flat wall portion surfaces to each adjacent concavity.

The fixed shaft may comprise a split pin with fork legs and each projection may be located on a said fork leg.

The first shaft may comprise a substantially hollow bobbin.

Said at least one formation may be located on an inner surface of the bobbin. In other embodiments it may be located on an outer surface thereof. Said engagement surface may extend partially along said bobbin, a remainder of the respective inner or outer surface having a generally smooth journal portion along at least a portion thereof.

The drive system may comprise a tooth ratchet wheel arranged to act upon a second shaft which is located at the second station, the second shaft being rotatable to wind the tape onto the second shaft.

The second shaft may be located on a main body of the dose counter spaced from and parallel to the first shaft.

The ratchet wheel may be fixed to the second shaft is arranged to rotate therewith. The ratchet wheel may be secured to an end of the second shaft and aligned coaxially with the second shaft.

The dose counter may include anti-back drive system which is arranged to restrict motion of the second shaft. The anti-back drive system may include a substantially fixed tooth arranged to act upon teeth of the ratchet wheel.

According to a further aspect of the present invention, a dose counter includes an anti-back drive system which is arranged to restrict motion of the second shaft in a tape winding direction.

According to a further aspect of the present invention there is provided a shaft for holding counter tape in a dose counter for an inhaler, the shaft having an engagement

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surface including incrementally spaced formations located around a periphery thereof, the formations comprising a series of curved concavities and convex portions.

The shaft may comprise a hollow bobbin.

The engagement surface may be a generally cylindrical inwardly directed surface.

The engagement surface may include a flat surface wall portion joining each concavity and convex wall portion.

Each concavity may comprise a radiused wall portion.

Each convex wall portion may comprise a radiused wall portion.

Said concavities may be regularly spaced around a longitudinal axis of the shaft.

Said convex wall portions may be regularly spaced around a longitudinal axis of the shaft.

In some embodiments there may be from eight to twelve said concavities and/or concavities regularly spaced around a longitudinal axis thereof.

One embodiment includes ten said concavities and/or convex wall portions regularly spaced around a longitudinal axis of the shaft.

According to a further aspect of the present invention there is provided a shaft and counter tape assembly for use in a dose counter for an inhaler, the assembly comprising a rotatable shaft and a counter tape which is wound around the shaft and is adapted to unwind therefrom upon inhaler actuation, the shaft having an engagement surface which includes incrementally spaced formations located around a periphery thereof.

According to a further aspect of the present invention there is provided an inhaler for the inhalation of medication and the like, the inhaler including a dose counter as in the first aspect of the present invention.

A preferred construction consists of a manually operated metered dose inhaler including a dose counter chamber including a dose display tape driven by a ratchet wheel which is driven in turn by an actuator pawl actuated by movement of a canister, the tape unwinding from a stock bobbin during use of the inhaler, a rotation regulator being provided for the stock bobbin and comprising a wavelike engagement surface with concavities which engage against control elements in the form of protrusions on resilient forks of a split pin thereby permitting incremental unwinding of the stock bobbin yet resisting excessive rotation if the inhaler is dropped onto a hard surface.

According to another aspect of the present invention there is provided a dose counter for a metered dose inhaler having a body arranged to retain a medicament canister of predetermined configuration for movement of the canister relative thereto; the dose counter comprising: an incremental counting system for counting doses, the incremental counting system having a main body, an actuator arranged to be driven in response to canister motion and to drive an incremental output member in response to canister motion, the actuator and incremental output member being configured to have predetermined canister fire and count configurations in a canister fire sequence, the canister fire configuration being determined by a position of the actuator relative to a datum at which the canister fires medicament and the count configuration being determined by a position of the actuator relative to the datum at which the incremental count system makes an incremental count, wherein the actuator is arranged to reach a position thereof in the count configuration at or after a position thereof in the canister fire configuration.

This arrangement has been found to be highly advantageous since it provides an extremely accurate dose counter

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which is suitable for use with manually operated metered dose inhalers. It has been found that dose counters with these features have a failure rate of less than 50 failed counts per million full canister activation depressions. It has been found in the course of making the present invention that highly reliable counting can be achieved with the dose counter counting at or soon after the point at which the canister fires. It has been is covered by the present inventors that momentum and motion involved in firing the canister, and in some embodiments a slight reduction in canister back pressure on the user at the time of canister firing, can very reliably result in additional further motion past the count point.

The actuator and incremental counting system may be arranged such that the actuator is displaced less than 1 mm, typically 0.25 to 0.75 mm, more preferably about 0.4 to 0.6 mm, relative to the body between its location in the count and fire configurations, about 0.48 mm being preferred. The canister, which can move substantially in line with the actuator, can reliably move this additional distance so as to achieve very reliable counting.

The incremental count system may comprise a ratchet mechanism and the incremental output member may comprise a ratchet wheel having a plurality of circumferentially spaced teeth arranged to engage the actuator.

The actuator may comprise an actuator pawl arranged to engage on teeth of the ratchet wheel. The actuator pawl may be arranged to be connected to or integral with an actuator pin arranged to engage and be depressed by a medicament canister bottom flange. The actuator pawl may be generally U-shaped having two parallel arms arranged to pull on a central pawl member arranged substantially perpendicular thereto. This provides a very reliable actuator pawl which can reliably pull on the teeth of the ratchet wheel.

The incremental count system may include a tape counter having tape with incremental dose indicia located thereon, the tape being positioned on a tape stock bobbin and being arranged to unwind therefrom.

The actuator and incremental output member may be arranged to provide a start configuration at which the actuator is spaced from the ratchet output member, a reset configuration at which the actuator is brought into engagement with the incremental output member during a canister fire sequence, and an end configuration at which the actuator disengages from the ratchet output during a canister fire sequence.

The actuator may be arranged to be located about 1.5 to 2.0 mm, from its location in the fire configuration, when in the start configuration, about 1.80 mm being preferred.

The actuator may be arranged to be located about 1.0 to 1.2 mm, from its location in the fire configuration, when in the reset configuration, about 1.11 mm being preferred.

The actuator may be arranged to be located about 1.1 to 1.3 mm, from its location in the fire configuration, when in the end configuration, about 1.18 mm being preferred.

These arrangements provide extremely reliable dose counting, especially with manually operated canister type metered dose inhalers.

The main body may include a formation for forcing the actuator to disengage from the incremental output member when the actuator is moved past the end configuration. The formation may comprise a bumped up portion of an otherwise generally straight surface against which the actuator engages and along which it is arranged to slide during a canister firing sequence.

The dose counter may include a counter pawl, the counter pawl having a tooth arranged to engage the incremental

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output member, the tooth and incremental output member being arranged to permit one way only incremental relative motion therebetween. When the incremental output member comprises a ratchet wheel, the tooth can therefore serve as an anti-back drive tooth for the ratchet wheel, thereby permitting only one way motion or rotation thereof.

The counter pawl may be substantially fixedly mounted on the main body of the incremental count system and the counter pawl may be arranged to be capable of repeatedly engaging equi-spaced teeth of the incremental output member in anti-back drive interlock configurations as the counter is operated. The counter pawl may be positioned so that the incremental output member is halfway, or substantially halfway moved from one anti-back drive interlock configuration to the next when the actuator and incremental output member are in the end configuration thereof. This is highly advantageous in that it minimises the risk of double counting or non-counting by the dose counter.

According to a further aspect of the invention there is provided an inhaler comprising a main body arranged to retain a medicament canister of predetermined configuration and a dose counter mounted in the main body.

The inhaler main body may include a canister receiving portion and a separate counter chamber, the dose counter being located within the main body thereof, the incremental output member and actuator thereof inside the counter chamber, the main body of the inhaler having wall surfaces separating the canister-receiving portion and the counter chamber, the wall surfaces being provided with a communication aperture, an actuation member extending through the communication aperture to transmit canister motion to the actuator.

According to a further aspect of the present invention there is a provided an inhaler for metered dose inhalation, the inhaler comprising a main body having a canister housing arranged to retain a medicament canister for motion therein, and a dose counter, the dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of a medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation located directly adjacent the actuation member.

This is highly advantageous in that the first inner wall canister support formation can prevent a canister from rocking too much relative to the main body of the inhaler. Since the canister may operate the actuation member of the dose counter, this substantially improves dose counting and avoids counter errors.

The canister housing may have a longitudinal axis which passes through a central outlet port thereof, the central outlet port being arranged to mate with an outer canister fire stem of a medicament canister, the inner wall canister support formation, the actuation member and the outlet port lying in a common plane coincident with the longitudinal axis. Accordingly, this construction may prevent the canister from rocking towards the position of the dose counter actuation member, thereby minimising errors in counting.

The canister housing may have a further inner canister wall support formation located on the inner wall opposite, or substantially opposite, the actuation member. Accordingly, the canister may be supported against rocking motion away from the actuator member so as to minimise count errors.

The canister housing may be generally straight and tubular and may have an arrangement in which each said inner wall support formation comprises a rail extending longitudinally along the inner wall.



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Each said rail may be stepped, in that it may have a first portion located towards a medicine outlet end or stem block of the canister housing which extends inwardly a first distance from a main surface of the inner wall and a second portion located toward an opposite end of the canister chamber which extends inwardly a second, smaller distance from the main surface of the inner wall. This may therefore enable easy insertion of a canister into the canister housing such that a canister can be lined up gradually in step wise function as it is inserted into the canister housing.

The inhaler may include additional canister support rails which are spaced around an inner periphery of the inner wall of the canister housing and which extend longitudinally therealong.

At least one of the additional rails may extend a constant distance inwardly from the main surface of the inner wall.

At least one of the additional rails may be formed with a similar configuration to the first inner wall canister support formation.

The dose counter may, apart from said at least a portion of the actuation member, be located in a counter chamber separate from the canister housing, the actuation member comprising a pin extending through an aperture in a wall which separates the counter chamber and the canister housing.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicaments having: a body for retaining a medicament store; the body including a dose counter, the dose counter having a moveable actuator and a return spring for the actuator, the return spring having a generally cylindrical and annular end; the body having a support formation therein for supporting said end of the return spring, the support formation comprising a shelf onto which said end is engageable and a recess below the shelf.

This shelf and recess arrangement is highly advantageous since it allows a tool (such as manual or mechanical tweezers) to be used to place the return spring of the actuator onto the shelf with the tool then being withdrawn at least partially via the recess.

The shelf may be U-shaped.

The support formation may include a U-shaped upstanding wall extending around the U-shaped shelf, the shelf and upstanding wall thereby forming a step and riser of a stepped arrangement.

The recess below the shelf may also be U-shaped.

At least one chamfered surface may be provided at an entrance to the shelf. This may assist in inserting the actuator and return spring into position.

A further aspect of the invention provides a method of assembly of an inhaler which includes the step of locating said end of said spring on the shelf with an assembly tool and then withdrawing the assembly tool at least partly via the recess. This assembly method is highly advantageous compared to prior art methods in which spring insertion has been difficult and in which withdrawal of the tool has sometimes accidentally withdrawn the spring again.

The cylindrical and annular end of the spring may be movable in a direction transverse to its cylindrical extent into the shelf while being located thereon.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament, the inhaler having a body for retaining a medicament store; and a dose counter, the dose counter having a moveable actuator and a chassis mounted on the body; the chassis being heat staked in position on the body. This is highly advantageous in that the chassis can be very accurately positioned

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and held firmly in place, thereby further improving counting accuracy compared to prior art arrangements in which some movement of the chassis relative to the body may be tolerated in snap-fit connections.

The chassis may have at least one of a pin or aperture heat staked to a respective aperture or pin of the body.

The chassis may have a ratchet counter output member mounted thereon.

The ratchet counter output member may comprise a ratchet wheel arranged to reel in incrementally a dose meter tape having a dosage indicia located thereon.

According to a further aspect of the present invention there is provided a method of assembling an inhaler including the step of heat staking the chassis onto the body. The step of heat staking is highly advantageous in fixedly positioning the chassis onto the body in order to achieve highly accurate dose counting in the assembled inhaler.

The method of assembly may include mounting a spring-returned ratchet actuator in the body before heat staking the chassis in place. The method of assembly may include pre-assembling the chassis with a dose meter tape prior to the step of heat staking the chassis in place. The method of assembly may include attaching a dose meter cover onto the body after the heat staking step. The cover may be welded onto the body or may in some embodiments be glued or otherwise attached in place.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament and having a body, the body have a main part thereof for retaining a medicament store; and a dose counter, the dose counter being located in a dose counter chamber of the body which is separated from the main part of the body, the dose counter chamber of the body having a dosage display and being perforated so as to permit the evaporation of water or aqueous matter in the dose counter chamber into the atmosphere.

This is highly advantageous since it enables the inhaler to be thoroughly washed and the dose counting chamber can thereafter dry out fully.

The display may comprise a mechanical counter display inside the dose counter chamber and a window for viewing the mechanical counter display. The mechanical counter display may comprise a tape. The perforated dose counter chamber may therefore enable reliable washing of the inhaler, if desired by the user, and may therefore dry out without the display window misting up.

The dose counter chamber may be perforated by a drain hole formed through an outer hole of the body. The drain hole may be located at a bottom portion of the body of the inhaler, thereby enabling full draining of the inhaler to be encouraged after washing when the inhaler is brought into an upright position.

According to a further aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a display tape arranged to be incrementally driven from a tape stock bobbin onto an incremental tape take-up drive shaft, the bobbin having an internal bore supported by and for rotation about a support shaft, at least one of the bore and support shaft having a protrusion which is resiliently biased into frictional engagement with the other of the bore and support shaft with longitudinally extending mutual frictional interaction. This arrangement may provide good friction for the bobbin, thereby improving tape counter display accuracy and preventing the bobbin from unwinding undesirably for example if the inhaler is accidentally dropped.

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The support shaft may be forked and resilient for resiliently biasing the support shaft and bore into frictional engagement.

The support shaft may have two forks, or more in some cases, each having a radially extending protrusion having a friction edge extending therealong parallel to a longitudinal axis of the support shaft for frictionally engaging the bore of the support shaft with longitudinally extending frictional interaction therebetween.

The bore may be a smooth circularly cylindrical or substantially cylindrical bore.

Each of the above inhalers in accordance with aspects of the present invention may have a medicament canister mounted thereto.

The canister may comprise a pressurised metered dose canister having a reciprocally movable stem extending therefrom and movable into a main canister portion thereof for releasing a metered dose of medicament under pressure, for example by operating a metered dose valve inside the canister body. The canister may be operable by pressing by hand on the main canister body.

In cases in which one or more support rails or inner wall support formations are provided, the canister may at all times when within the canister chamber have a clearance of about 0.25 to 0.35 mm from the first inner wall support formation. The clearance may be almost exactly 0.3 mm. This clearance which may apply to the canister body itself or to the canister once a label has been applied, is enough to allow smooth motion of the canister in the inhaler while at the same time preventing substantial rocking of the canister which could result in inaccurate counting by a dose counter of the inhaler, especially when lower face of the canister is arranged to engage an actuator member of the dose counter for counting purposes.

According to a further aspect of the invention, a method of assembling a dose counter for an inhaler comprises the steps of providing a tape with dosing indicia thereon; providing tape positioning indicia on the tape; and stowing the tape while monitoring for the tape positioning indicia with a sensor. The method advantageously permits efficient and accurate stowing of the tape, e.g. by winding.

The dosing indicia may be provided as numbers, the tape positioning indicia may be provided as one or more lines across the tape. The stowing step comprises winding the tape onto a bobbin or shaft, and, optionally, stopping winding when the positioning indicia are in a predetermined position. The tape may be provided with pixelated indicia at a position spaced along the tape from the positioning indicia. The tape may also be provided with a priming dot.

According to a further aspect of the invention, a tape system for a dose counter for an inhaler has a main elongate tape structure, and dosing indicia and tape positioning indicia located on the tape structure. The tape positioning indicia may comprise at least one line extending across the tape structure. The tape system may comprise pixelated indicia located on the tape structure and spaced from the positioning indicia. The tape system may comprise a priming dot located on the tape structure. The positioning indicia may be located between the timing dot and the pixelated indicia. The main elongate tape structure may have at least one end thereof wound on a bobbin or shaft.

A further aspect of the invention provides a method of designing an incremental dose counter for an inhaler comprising the steps of calculating nominal canister fire and dose counter positions for a dose counter actuator of the inhaler; calculating a failure/success rate for dose counters built to tolerance levels for counting each fire of inhalers in

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which the dose counter actuators may be applied; and selecting a tolerance level to result in said failure/success rate to be at or below/above a predetermined value. This is highly advantageous in that it allows an efficient and accurate prediction of the reliability of a series of inhaler counters made in accordance with the design.

The method of designing may include selecting the failure/success rate as a failure rate of no more than one in 50 million. The method of designing may include setting an average count position for dose counters built to the tolerances to be at or after an average fire position thereof during canister firing motion. The method of designing may include setting the average count position to be about 0.4 to 0.6 mm after the average fire position, such as about 0.48 mm after. The method of designing may include setting tolerances for the standard deviation of the fire position in dose counters built to the tolerances to be about 0.12 to 0.16 mm, such as about 0.141 mm. The method of designing may include setting tolerances for the standard deviation of the count positions in dose counters built to the tolerances to be about 0.07 to 0.09 mm, such as about 0.08 mm. A further aspect of the invention provides a computer implemented method of designing an incremental dose counter for an inhaler which includes the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing in a production run a series of incremental dose counters for inhalers which comprises manufacturing the series of dose counters in accordance with the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing a series of incremental dose counters for inhalers, which comprises manufacturing the dose counters with nominal canister fire and dose count positions of a dose counter actuator relative to a dose counter chassis (or inhaler main body), and which includes building the dose counters with the average dose count position in the series being, in canister fire process, at or after the average canister fire position in the series.

According to a further aspect of the invention, the method provides fitting each dose counter in the series of incremental dose counters to a corresponding main body of an inhaler.

These aspects advantageously provide for the production run of a series of inhalers and dose counters which count reliably in operation.

According to a further aspect of the invention, an incremental dose counter for a metered dose inhaler has a body arranged to retain a canister for movement of the canister relative thereto, the incremental dose counter having a main body, an actuator arranged to be driven and to drive an incremental output member in a count direction in response to canister motion, the actuator being configured to restrict motion of the output member in a direction opposite to the count direction. This advantageously enables an inhaler dose counter to keep a reliable count of remaining doses even if dropped or otherwise jolted.

The output member may comprise a ratchet wheel. The actuator may comprise a pawl and in which the ratchet wheel and pawl are arranged to permit only one-way ratcheting motion of the wheel relative to the pawl. The dose counter may include an anti-back drive member fixed to the main body. In a rest position of the dose counter, the ratchet wheel is capable of adopting a configuration in which a back surface of one tooth thereof engages the anti-back drive member and the pawl is spaced from an adjacent back

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surface of another tooth of the ratchet wheel without positive drive/blocking engagement between the pawl and wheel.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be carried out in various ways and preferred embodiment of a dose counter, inhaler and methods of assembly, design and manufacture will now be described with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of a main body of an embodiment of an inhaler related to the invention together with a mouthpiece cap therefor;

FIG. 2 is a top plan view of the components as shown in FIG. 1;

FIG. 3A is a section on the plane 3A-3A in FIG. 2;

FIG. 3B is a view corresponding to FIG. 3A but with a dose counter fitted to the main body of the inhaler;

FIG. 4A is an exploded view of the inhaler main body, mouthpiece cap, dose counter and a dose counter window;

FIG. 4B is a view in the direction 4B in FIG. 4C of a spring retainer of the dose counter;

FIG. 4C is a top view of the spring retainer of FIG. 4B;

FIG. 5 is a bottom view of the assembled inhaler main body, mouthpiece cap, dose counter and dose counter window;

FIGS. 6A, 6B, 6C, 6D, 6E, 6F, 6G and 6H are various views of dose counter components of the inhaler;

FIGS. 7A and 7B are sectional views showing canister clearance inside the main body of the inhaler;

FIG. 7C is a further sectional view similar to that of FIG. 7B but with the canister removed;

FIG. 7D is a top plan view of the inhaler main body;

FIGS. 8A, 8B, 8C and 8D show the inhaler main body and dose counter components during assembly thereof;

FIG. 9 shows a sectional side view of a datum line for an actuator pawl of the dose counter;

FIGS. 10A, 10B, 10C, 10D, 10E and 10F show various side views of positions and configurations of the actuator pawl, a ratchet wheel, and a count pawl;

FIG. 11 shows distributions for tolerances of start, reset, fire, count and end positions for the actuator of the dose counter;

FIG. 12 is an enlarged version of part of FIG. 4A;

FIG. 13 shows an end portion of a tape of the dose counter;

FIG. 14 shows a computer system for designing the dose counter;

FIG. 15 is an isometric view of a stock bobbin modified in accordance with the present invention for use in the dose counter of the inhaler of FIGS. 1 to 14;

FIG. 16 shows an end view of the stock bobbin of FIG. 15;

FIG. 17 is a section through a longitudinal axis of the stock bobbin of FIGS. 15 and 16;

FIGS. 18A to 18C are views of the stock bobbin of FIGS. 15 to 17 mounted in the dose counter chassis of FIGS. 1 to 14, with the control elements of the forks of the second shaft (or split pin) having a profile slightly different to that in FIG. 6F, with the forks in a compressed configuration;

FIGS. 19A to 19C are views equivalent to FIGS. 18A to 18C but with the forks in a more expanded configuration due to a different rotational position of the stock bobbin;

FIG. 20 is an isometric view of the chassis assembled and including the stock bobbin of FIGS. 15 to 17 but excluding the tape for reasons of clarity;

FIG. 21 is a view of a preferred embodiment of a dry powder inhaler in accordance with the present invention;

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FIG. 22 is an exploded view of the inhaler of FIG. 21;

FIG. 23 is a view of a dose counter of the inhaler of FIG. 21;

FIG. 24 is an exploded view of the dose counter shown in FIG. 23;

FIG. 25 is an exploded view of parts of the inhaler of FIG. 21; and

FIG. 26 is a view of a yoke of the inhaler of FIG. 21.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a main body 10 of a manually operated metered dose inhaler 12 in accordance with an embodiment related to the present invention and having a mouthpiece cap 14 securable over a mouthpiece 16 of the main body.

The main body has a canister chamber 18 into which a canister 20 (FIG. 7A) is slideable. The canister 20 has a generally cylindrical main side wall 24, joined by a tapered section 26 to a head portion 28 having a substantially flat lower face 30 which has an outer annular drive surface 32 arranged to engage upon and drive an actuation pin 34 of a dose counter 36 as will be described. Extending centrally and axially from the lower face 30 is a valve stem 38 which is arranged to sealingly engage in a valve stem block 40 of the main body 10 of the inhaler 12. The valve stem block 40 has a passageway 42 leading to a nozzle 44 for directing the contents of the canister 20, namely active drug and propellant, towards an air outlet 46 of the inhaler main body 12. It will be appreciated that due to gaps 48 between the canister 20 and an inner wall 50 of the main body 10 of the inhaler 12 an open top 52 of the main body 10 forms an air inlet into the inhaler 12 communicating via air passageway 54 with the air outlet 46, such that canister contents exiting nozzle 44 mix with air being sucked by the user through the air passageway 54 in order to pass together through the air outlet and into the mouth of the user (not shown).

The dose counter 36 will now be described. The dose counter 36 includes an actuation pin 34 biased upwardly from underneath by a return spring 56 once installed in the main body 10. As best shown in FIGS. 4A, 6H and 8A, the pin 34 has side surfaces 58, 60 arranged to slide between corresponding guide surfaces 62, 64 located in a dose counter chamber 66 of the main body 10, as well as an end stop surface 68 arranged to engage a corresponding end stop 70 formed in the dose counter chamber 66 to limit upward movement of the pin 34. The pin 34 has a top part 72 which is circularly cylindrical and extends through an aperture 74 formed through a separator wall 76 which separates the canister chamber 18 from the dose counter chamber 66. The top part 72 of the pin 34 has a flat top surface 78 which is arranged to engage the outer annular drive surface 32 of the canister 20.

The actuation pin 34 is integrally formed with a drive or actuator pawl 80. The actuator pawl 80 has a generally inverted U-shape configuration, having two mutually spaced and parallel arms 82, 84 extending from a base portion of the actuation pin 34, each holding at respective distal ends 88 thereof opposite ends of a pawl tooth member 90 which extends in a direction substantially perpendicular to the arms 82, 84, so as to provide what may be considered a "saddle" drive for pulling on each of the 11 drive teeth 92 of a ratchet wheel 94 of an incremental drive system 96 or ratchet mechanism 96 of the dose counter 36. As shown for example in FIG. 10B, the pawl tooth member 90 has a sharp lower longitudinal side edge 98 arranged to engage the drive teeth 92, the edge-to-surface contact provided by this engagement



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providing very accurate positioning of the actuator pawl **80** and resultant rotational positioning of the ratchet wheel **94**.

The dose counter **36** also has a chassis preassembly **100** which, as shown in FIGS. **4A** and **6A**, includes a chassis **102** having a first shaft **104** receiving the ratchet wheel **94** which is secured to a tape reel shaft **106**, and a second shaft (or split pin) **108** which is parallel to and spaced from the first shaft **104** and which slidably and rotationally receives a tape stock bobbin **110**.

As shown in FIG. **6B**, when the inhaler has not been used at all, the majority of a tape **112** is wound on the tape stock bobbin **110** and the tape **112** has a series of regularly spaced numbers **114** displayed therealong to indicate a number of remaining doses in the canister **20**. As the inhaler is repeatedly used, the ratchet wheel **94** is rotated by the actuator pawl **80** due to operation of the actuation pin **34** by the canister **20** and the tape **112** is incrementally and gradually wound on to the tape reel shaft **106** from the second shaft **108**. The tape **112** passes around a tape guide **116** of the chassis **102** enabling the numbers **114** to be displayed via a window **118** in a dose counter chamber cover **120** having a dose marker **132** formed or otherwise located thereon.

As shown in FIGS. **6A** and **6D**, the second shaft **108** is forked with two forks **124**, **126**. The forks **124**, **126** are biased away from one another. The forks have located thereon at diametrically opposed positions on the second shaft **108** friction or control elements **128**, **130**, one on each fork. Each control element extends longitudinally along its respective fork **124**, **126** and has a longitudinally extending friction surface **132**, **134** which extends substantially parallel to a longitudinal axis of the second shaft and is adapted to engage inside a substantially cylindrical bore **136** inside the tape stock bobbin **110**. This control arrangement provided between the bore **136** and the control elements **128**, **130** provides good rotational control for the tape stock bobbin **110** such that it does not unwind undesirably such as when the inhaler is dropped. The tape force required to unwind the tape stock bobbin **110** and overcome this friction force is approximately 0.1 N.

As can be seen in FIG. **6D**, as well as FIGS. **6G** and **10A** to **10F**, the chassis **102** is provided with an anti-back drive tooth **138** or count pawl **138** which is resiliently and substantially fixedly mounted thereto. As will be described below and as can be seen in FIGS. **10A** to **10F**, when the actuation pin **34** is depressed fully so as to fire the metered valve (not shown) inside the canister **20**, the actuator pawl **80** pulls down on one of the teeth **92** of the ratchet wheel **94** and rotates the wheel **94** anticlockwise as shown in FIG. **6D** so as to jump one tooth **92** past the count pawl **138**, thereby winding the tape **112** a distance incrementally relative to the dose marker **122** on the dose counter chamber **120** so as to indicate that one dose has been used.

With reference to FIG. **10B**, the teeth of the ratchet wheel **94** have tips **143** which are radiused with a 0.1 mm radius between the flat surfaces **140**, **142**. The ratchet wheel **94** has a central axis **145** which is 0.11 mm above datum plane **220** (FIG. **9**). A top/nose surface **147** of the anti-back drive tooth **138** is located 0.36 mm above the datum plane **220**. The distance vertically (i.e. transverse to datum plane **220**—FIG. **9**) between the top nose surface **147** of the anti-back drive tooth is 0.25 mm from the central axis **145** of the wheel **94**. Bump surface **144** has a lateral extent of 0.20 mm, with a vertical length of a flat **145'** thereof being 1 mm, the width of the bump surface being 1.22 mm (in the direction of the axis **145**), the top **149** of the bump surface **144** being 3.02 mm vertically below the axis **145**, and the flat **145'** being spaced a distance sideways (i.e. parallel to the datum plane

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**220**) 2.48 mm from the axis **145**. The top surface **78** of the pin **34** (FIG. **6H**) is 11.20 mm above the datum plane **220** (FIG. **9**) when the actuator pawl **80** and pin **34** are in the start configuration. The length of the valve stem **22** is 11.39 mm and the drive surface **32** of the canister **20** is 11.39 mm above the datum plane **220** when the canister is at rest waiting to be actuated, such that there is a clearance of 0.19 mm between the canister **20** and the pin **34** in this configuration.

FIGS. **10A** and **10B** show the actuator pawl **80** and ratchet wheel **94** and count pawl **138** in a start position in which the flat top **78** of the pin **34** has not yet been engaged by the outer annular drive surface **32** of the canister **20** or at least has not been pushed down during a canister depression.

In this "start" position, the count pawl **138** engages on a non-return back surface **140** of one of the teeth **92** of the ratchet wheel **94**. The lower side edge **98** of the actuator pawl is a distance "D" (FIG. **9**) 1.33 mm above datum plane **220** which passes through bottom surface or shoulder **41** of valve stem block **40**, the datum plane **220** being perpendicular to a main axis "X" of the main body **10** of the inhaler **12** which is coaxial with the centre of the valve stem block bore **43** and parallel to a direction of sliding of the canister **20** in the main body **10** of the inhaler **12** when the canister is fired.

As shown in FIG. **10B**, an advantageous feature of the construction is that the pawl tooth/actuator **90** acts as a supplementary anti-back drive member when the inhaler **12** is not being used for inhalation. In particular, if the inhaler **12** is accidentally dropped, resulting in a jolt to the dose counter **36** then, if the wheel **94** would try to rotate clockwise (backwards) as shown in FIG. **10B**, the back surface **140** of a tooth will engage and be blocked by the tooth member **90** of the pawl **80**. Therefore, even if the anti-back drive tooth **138** is temporarily bent or overcome by such a jolt, undesirable backwards rotation of the wheel **94** is prevented and, upon the next canister firing sequence, the pawl **90** will force the wheel **94** to catch up to its correct position so that the dose counter **36** continues to provide correct dosage indication.

FIG. **10C** shows a configuration in which the actuator pawl **80** has been depressed with the pin **34** by the canister **20** to a position in which the side edge **98** of the pawl tooth member **90** is just engaged with one of the teeth **92** and will therefore upon any further depression of the pin **34** begin to rotate the wheel **94**. This is referred to as a "Reset" position or configuration. In this configuration, the lower side edge **98** of the actuator **80** is 0.64 mm above the datum plane **220**.

FIG. **10D** shows a configuration in which the actuator pawl **80** has been moved to a position lower than that shown in FIG. **10C** and in which the metered dose valve (not shown) inside the canister has at this very position fired in order to eject active drug and propellant through the nozzle **44**. It will be noted that in this configuration the count pawl **138** is very slightly spaced from the back surface **140** of the same tooth **92** that it was engaging in the configuration of FIG. **10D**. The configuration shown in FIG. **10D** is known as a "Fire" configuration. In this configuration the lower side edge **98** of the actuator **80** is 0.47 mm below the datum plane **220**.

FIG. **10E** shows a further step in the sequence, called a "Count" position in which the actuator pawl **80** has rotated the ratchet wheel **94** by the distance circumferentially angularly between two of the teeth **92**, such that the count pawl **138** has just finished riding along a forward surface **142** of one of the teeth **92** and has resiliently jumped over the tooth into engagement with the back surface **140** of the next tooth. Accordingly, in this "Count" configuration, a sufficiently

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long stroke movement of the pin 34 has occurred that the tape 112 of the dose counter 36 will just have counted down one dose. In this configuration, the lower side edge 98 of the actuator is 0.95 mm below the datum plane 220. Accordingly, in this position, the actuator 80 generally, including edge 98, is 0.48 mm lower than in the fire configuration. It has been found that, although the count configuration happens further on than the fire configuration, counting is highly reliable, with less than one in 50 failed counts per million. This is at least partially due to momentum effects and to the canister releasing some back pressure on the user in some embodiments as its internal metering valve fires.

In the configuration of FIG. 10F, the pawl 80 has been further depressed with the pin 34 by the canister 20 to a position in which it is just disengaging from one of the teeth 92 and the actuator pawl 80 is assisted in this disengagement by engagement of one of the arms 84 with a bump surface 144 on the chassis 102 (see FIG. 6G) and it will be seen at this point of disengagement, which is called an "End" configuration, the count pawl 138 is positioned exactly halfway or substantially halfway between two of the drive teeth 92. This advantageously means therefore that there is a minimum chance of any double counting or non-counting, which would be undesirable. In the end configuration, the side edge 98 of the actuator is 1.65 mm below the datum plane 220. It will be appreciated that any further depression of the actuator pawl 80 and pin 34 past the "End" configuration shown in FIG. 10F will have no effect on the position of the tape 112 displayed by the dose counter 36 since the actuator pawl 80 is disengaged from the ratchet wheel 94 when it is below the position shown in FIG. 10F.

As shown in FIGS. 7C and 7D, the inner wall 50 of the main body 10 is provided with a two-step support rail 144 which extends longitudinally along inside the main body and is located directly adjacent the aperture 74. As shown in FIG. 7B a diametrically opposed two-step support rail 146 is also provided and this diametrically opposed in the sense that a vertical plane (not shown) can pass substantially directly through the first rail 144, the aperture 74, a central aperture 148 of the valve stem block 40 (in which canister stem 25 is located) and the second two-step support rail 146. As shown in FIG. 7A and schematically in FIG. 7B, the rails 144, 146 provide a maximum clearance between the canister 20 and the rails 144, 146 in a radial direction of almost exactly 0.3 mm, about 0.25 to 0.35 mm being a typical range. This clearance in this plane means that the canister 20 can only rock backwards and forwards in this plane towards away from the actuation pin 34. A relatively small distance and this therefore prevents the canister wobbling and changing the height of the actuation pin 34 as to undesirably alter the accuracy of the dose counter 36. This is therefore highly advantageous.

The inner wall 50 of the main body 10 is provided with two further two-step rails 150 as well as two pairs 152, 154 of rails extending different constant radial amounts inwardly from the inner wall 50, so as to generally achieve a maximum clearance of almost exactly 0.3 mm around the canister 20 for all of the rails 144, 146, 150, 152, 154 spaced around the periphery of the inner wall 50, in order to prevent undue rocking while still allowing canister motion freely inside the inhaler 12. It will be clear from FIG. 7C for example that the two-step rails have a first portion near an outlet end 156 of the canister chamber 18, the first portion having a substantially constant radial or inwardly-extending width, a first step 160 leading to a second portion 162 of the rail, the second portion 102 having a lesser radial or inwardly

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extending extent than the first portion 156, and finally a second step 164 at which the rail merges into the main inner wall 50 main surface.

A method of assembling the inhaler 12 will now be described.

With reference to FIG. 8A, the main body 10 of the inhaler 12 is formed by two or more plastics mouldings which have been joined together to the configuration shown.

As shown in FIG. 8B, the actuator pawl 80 and pin 34 are translated forward into position into a pin receiving area 166 in the dose counter chamber 66 and the pin 34 and actuator 80 may then be raised until the pin 34 emerges through the aperture 74.

Next, the return spring 56 may be inserted below the pin 34 and a generally cylindrical annular lower end 168 of the spring 56 may be moved by a tweezer or tweezer-like assembly tool (not shown) into engagement with a shelf 170 of a spring retainer 172 in the dose counter chamber 66. The spring retainer 172 is U-shaped and the shelf 170 is U-shaped and has a recess 174 formed below it. As shown in FIGS. 4B, 4C and 12 shelf 170 includes three chamfer surfaces 176, 178, 180 arranged to assist in moving the lower end of the spring 168 into position onto the shelf using the assembly tool (not shown). Once the lower end of the spring 168 is in place, the assembly tool (not shown) can easily be removed at least partly via the recess 174 below the lower end 168 of the spring 56.

The tape 112 is attached at one end (not shown) to the tape stock bobbin 110 and is wound onto the bobbin by a motor 200 (FIG. 13) having a hexagonal output shaft 202 which engages in a hexagonal socket 204 (FIG. 6B) of the bobbin. During winding, the tape is monitored by a sensor 206, which may be in the form of a camera or laser scanner, which feeds data to a computer controller 205 for the motor 200. The controller 205 recognises three positioning markers 210 in the form of lines across the tape 112 and stops the motor 202 when the tape 112 is nearly fully wound onto the bobbin 110, such that the distal end 212 of the tape 112 can be secured, e.g. by adhesive, to the tape reel shaft 106. The controller 205 also recognises a pixelated tape size marker 214 observed by the sensor 206 and logs in a stocking system data store 217 details of the tape 112 such as the number of numbers 114 on the tape, such as one hundred and twenty or two hundred numbers 114. Next, the tape reel shaft is wound until an appropriate position of the lines 210 at which a priming dot 216 will, once the bobbin 110 and reel shaft 106 are slid onto the second shaft 108 and second shaft 104, be in a position to be located in the window 118 when the inhaler 12 is fully assembled. In the embodiments, the bobbin 110 and reel shaft 106 may be slid onto the shafts 108, 104 before the tape 112 is secured to the reel shaft 106 and the reel shaft may then be wound to position the priming dot 216.

Next, the assembled dose counter components of the chassis preassembly 100 shown in FIG. 6B may as shown in FIG. 8C be inserted into the dose counter chamber 66, with pins 182, 184, 186 formed on the main body 10 in the dose counter chamber 66 passing through apertures or slots 188, 190, 192 formed on the chassis 102, such that the pins 182, 184, 186 extend through (or at least into) the apertures or slots 188, 190, 192. With the chassis 102 being relatively firmly pushed towards the main body 10, the pins 182, 184, 186 are then heat staked and the chassis 102 is therefore after this held very firmly in position in the main body and is unable to move, thereby assisting in providing great accuracy for the dose counter 36. Next, as shown in FIG. 8D, the dose counter chamber cover 120 may be fitted over the dose

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counter chamber 66 and may be secured in place such as by welding, with the priming dot 216 being displayed through the window.

The user can, when readying the inhaler 12 for first use, prime the inhaler by depressing the canister 20 three times which will bring the first number 114 on the tape into display through the window 118 in place of the priming dot 216, the number 114 shown in FIG. 8D being "200", thereby indicating that 200 doses are remaining to be dispensed from the canister 20 and inhaler 12.

As shown in FIG. 8D, and in FIG. 5, an open drain hole 194 is provided at the bottom of the dose counter chamber 66 by a substantially semi-circular cut-out or recess formation 196 in a lower surface 198 of the main body 10 of the inhaler. Accordingly, if the user (not shown) should decide to wash the main body 10 of the inhaler, for example after encountering an unhygienic situation or simply as a matter of choice, the drain hole 194 allows initial draining of water from inside the dose counter chamber 66 and also thereafter evaporation of water or any aqueous matter in the dose counter chamber 66 so that the window 118 does not mist up undesirably.

FIG. 14 shows a computer system 230 for designing the dose counter 36 and in particular for calculating distributions representative of average positions and standard deviations in a production series of inhalers of the start, reset, fire, count and end positions of the actuator lower side edge 98 relative to the datum plane 220 (FIG. 9) and therefore of the actuator pawl 80 generally relative to the ratchet wheel 94, chassis 102 and, when the inhaler 12 is fully assembled, the main body 10 of the inhaler 12. The computer system 230 includes a data store 232, a CPU 234, an input device 236 (such as a keyboard or communication port) and an output device 238 (such as a communications port, display screen and/or printer). A user may enter data via the input device 236 which may be used by the CPU 234 in a mathematical calculation to predict count failure rates when the various dose counters are to be built in a series with dose counter positions set with given averages and standard deviations and taking into account any momentum/inertia effects and metering valve user-back-pressure reduction effect which will occur upon canister firing of a given type of canister. The computer system 230 is thus mathematically used to design the distributions. For the inhaler 12 described herein with the dose counter 36 and canister 20, the distributions are designed as shown in FIG. 11. The x axis shows distance of the lower side surface 98 of the actuator 80 above the datum plane 220 and the y axis is representative of the distribution. Thus, curve 240 shows that the start configuration has an average 1.33 mm above the datum plane 200 (standard deviation is 0.1 mm), curve 242 shows that the reset configuration has an average of 0.64 mm above the datum plane 220 (standard deviation is 0.082 mm), curve 244 shows the fire configuration has an average 0.47 mm below the datum plane 220 (standard deviation is 0.141 mm), curve 246 shows the count configuration has an average 0.95 mm below the datum plane 220 (standard deviation is 0.080 mm), and curve 248 shows the end configuration has an average of 1.65 mm below the datum plane 220 (standard deviation is 0.144 mm).

FIGS. 15 to 20 show a version of the inhaler modified in accordance with the present invention. In these drawings, the same reference numerals have been used to those in the earlier drawings to denote the equivalent components. The inhaler 12 is the same as that in FIGS. 1 to 14 apart from the following modifications.

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First, it can be seen that there is a modification in that the drive teeth 92 of the ratchet wheel 94 have a different profile to that in FIGS. 1 to 14. There are also only nine ratchet teeth 94 in this embodiment instead of eleven.

Additionally, as shown in FIGS. 18C and 19C, the control elements 128, 130 on the forks 124, 126 of the second shaft 108 have a tapered profile which is different to the profile of the control elements 128, 130 shown in FIG. 6F. Either profile can be used in the embodiment of FIGS. 15 to 20 however.

Furthermore, as shown in FIG. 15, the tape stock bobbin 110 has an inwardly facing generally cylindrical engagement surface 300 with a wavelike form extending partially therealong. The engagement surface 300 has a cross-section 301 perpendicular to the longitudinal length of the stock bobbin 110 which is constant therealong. This cross-section 301 can be seen in FIG. 16 and consists of a series of ten regularly spaced concavities 302 and ten convex wall portions 304. The convex wall portions 304 are equi-spaced between the concavities 302. Each concavity 302 has a radius of 0.2 mm. Each convex wall portion 304 also has a radius of 0.2 mm. Finally, the cross section 301 also includes flat wall portions 306 between all of the radiused wall portions of the concavities 302 and convex wall portions 304. The geometry of the cross-section 301 is therefore defined by the radii of the concavities 302 and convex wall portions 304, the flat wall portions 306 and the fact that there are ten concavities 302 and convex wall portions 304.

The minor diameter of the engagement surface 300, i.e. between the tips of opposite convex wall portions 304, is 2.46 mm. The major diameter of the engagement surface 300, i.e. between the outermost portions of the concavities 302, is 2.70 mm. The undeformed tip to tip maximum diameter of the forks 124, 126 of the split pin (the second shaft) 108, i.e. in the region of the maximum radial extent of the control elements 128, 130, is 3.1 millimeters and it will therefore be appreciated that the forks 124, 126 are resiliently compressed once the stock bobbin 110 has been assembled onto the split pin 108 in all rotational configurations of the stock bobbin 110 relative to the split pin 108. The minimum gap between the forks 124, 126 in the plane of the cross sections of FIGS. 18C and 19C is 1 mm when the split pin 108 is in the undeformed, pre-inserted state. When the split pin 108 is at maximum compression, as shown in FIGS. 18A to 18C when the control elements 128, 130 are shown to be engaged on top of the convex wall portions 304, the gap 308 between the tips 310, 312 of the forks 124, 126 is 0.36 mm. On the other hand, when the split pin 108 is at minimum compression (once inserted into the stock bobbin) as shown in FIGS. 19A to 19C, when the control elements 128, 130 rest in the concavities 302, the gap between the tips 310, 312 of the forks 124, 126 is 0.6 mm. The control elements 128, 130 are outwardly radiused with a radius also of 0.2 mm such that they can just rest on the concavities 302 with full surface contact (at least at an axial location on the split pin where the tapered control elements are at their maximum radial extent), without rattling in, locking onto or failing to fit in the concavities 302. The radii of the control elements 128, 130 is therefore preferably substantially the same as the radii of the concavities 302.

It will be appreciated that whereas FIGS. 18B and 19B are end views along the coaxial axis of the stock bobbin 110 and split pin 108, FIGS. 18A and 19A are cross-sections. FIG. 19A is a section on the plane A-A' in FIG. 19C and FIG. 18A is a section at the same plane, but of course with the stock bobbin 110 rotated relative to the split pin 108.



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As the inhaler 12 is used and the ratchet wheel 94 rotates in order to count used doses, the stock bobbin rotates incrementally through rotational positions in which rotation is resisted, i.e. due to increasing compression of the split pin 108 at such rotational positions, and rotational positions in which rotation is promoted, i.e. due to decreasing compression of the split pin 108 at such rotational positions and this may involve a click forward of the stock bobbin 110 to the next position equivalent to that in FIGS. 19A to 19C in which the control elements 128, 130 of the split pin art located in the concavities 302. This functionality firstly allows the stock bobbin to unwind during use as required, but also prevents the tape 112 from loosening during transit if the inhaler 12 is dropped, such as onto a hard surface. This is highly advantageous, since the tape 11 is prevented from moving to a position in which it will give an incorrect reading regarding the number of doses in the canister.

During compression and expansion of the forks in the radial direction between the two configurations shown in FIGS. 18C and 19C, the forks 124, 126 rotate about a point 316 on the split pin where the forks 124, 126 come together. This rotational action means that there is a camming action between the forks 124, 126 and the engagement surface 300 without significant friction but, nevertheless, the resilient forces provided by the regulator formed by the engagement surface 300 and forks 124, 126 are able to regulate unwinding of the tape such that it does not easily occur during transit or if the inhaler 12 is dropped. It has been found during testing that a force of 0.3 to 0.4 N needs to be applied to the tape 112 to overcome the regulator at the stock bobbin 110. 0.32 N is achieved with the control elements 128 having the profile shown in FIG. 19C and 0.38 N is achieved with the profile of the control elements 128 altered to be as shown as described with reference to FIG. 6F. These forces are substantially higher than the 0.1 N force mentioned above and undesirable movement of the tape is substantially avoided even if the inhaler is dropped onto a hard surface. The modified arrangement of FIGS. 15 to 20 does not provide this force "constantly" such that there is overall not an undesirably high friction of the tape 112 as it passes over the other components of the dose counter because, due to the incremental nature of the resilient forces at the regulator, the tape 112 can incrementally relax as it slides over the stationary chassis components.

Instead of having ten concavities 302 and convex wall portions 304, other numbers may be used, such as 8 or 12. However, it is preferred to have an even number, especially since two control elements 128, 130 are provided, so that all of the control elements 128, 130 will expand and contract simultaneously. However, other arrangements are envisaged with 3 or more forks and the number of concavities/convex wall portions may be maintained as an integer divisible by the number of forks to maintain a system with simultaneous expansion/contraction. For example, the use of 9, 12 or 15 concavities/convex wall portions with 3 forks is envisaged.

Instead of having the engagement surface 300 on the inside of the stock bobbin 110, it could be placed on the outside of the stock bobbin 110 so as to be engaged by flexible external legs/pawls or similar.

It will be noted that the regulator provided by the engagement surface 300 and forks 124, 126 does not only allow rotation of the stock bobbin in one direction as is the case with the ratchet wheel 94. Rotation in both directions is possible, i.e. forwards and backwards. This means that during assembly, the stock bobbin 110 can be wound backwards during or after fitting the bobbin 100, shaft 106 and tape 112 onto the carriage 102, if desired.

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The stock bobbin 110 and the carriage 102 including the split pin 108 are both moulded of polypropylene material.

It will be seen from FIG. 16 that the cross-sectional shape 301 is not symmetrical within the hexagonal socket 204. This has enabled the hexagonal socket 204 to be maintained at a useful size while still allowing the desired size and geometry of the cross section 301 to fit without interfering with the hexagonal shape of the hexagonal socket 204 and also permits moulding to work during manufacture.

As shown in FIG. 17, the stock bobbin 110 has a series of four circumferential ribs 330 inside it and a spaced therealong. These hold the stock bobbin 110 on the correct side of the mould tool during moulding.

FIGS. 21 and 22 show a preferred embodiment in accordance with the invention of an inhaler 510 for dispensing a dry-powdered medicament in metered doses for patient inhalation. The inhaler 510 is as disclosed in FIGS. 1 to 16 or EP-A-1330280, the contents of which are hereby fully incorporated herein by reference, but with the stock bobbin 110 and second shaft 108 of the dose counter 516 modified so as to be as in FIGS. 15 to 20 hereof. Thus, the dry powder inhaler 510 generally includes a housing 518, and an assembly 512 received in the housing (see FIG. 21). The housing 518 includes a case 520 having an open end 522 and a mouthpiece 524 (FIG. 25) for patient inhalation, a cap 526 secured to and closing the open end 522 of the case 520, and a cover 528 pivotally mounted to the case 520 for covering the mouthpiece 524. As shown in FIG. 22, the inhaler 510 also includes an actuation spring 569, first yoke 566 with opening 572, bellows 540 with crown 574, a reservoir 514, second yoke 568 with hopper 542 and dose counter 516 mounted thereto, and case 520 has transparent window 5130 thereon for viewing dose counter tape indicia 5128. The dose metering system also includes two cams 570 mounted on the mouthpiece cover 528 and movable with the cover 528 between open and closed positions. The cams 570 each include an opening 580 for allowing outwardly extending hinges 582 of the case 520 to pass therethrough and be received in first recesses 584 of the cover 528. The cams 570 also include bosses 586 extending outwardly and received in second recesses 588 of the cover 528, such that the cover 528 pivots about the hinges 582 and the cams 570 move with the cover 528 about the hinges 582. As described in EP-A-1330280, cams 570 act upon cam followers 578 to move second yoke 568 up and down and thereby operate dose counter by engagement of pawl 5138 on the second yoke 568 with teeth 5136. Remaining components of the inhaler are provided as, and operate as described, in EP-A-1330280.

The dose counting system 516 therefore includes a ribbon or tape 5128 (FIGS. 23 & 24), having successive numbers or other suitable indicia printed thereon, in alignment with a transparent window 5130 provided in the housing 18 (see FIG. 22). The dose counting system 516 includes the rotatable stock bobbin 110 (as described above), an indexing spool 5134 rotatable in a single direction, and the ribbon 5128 rolled and received on the bobbin 110 and having a first end 5127 secured to the spool 5134, wherein the ribbon 5128 unrolls from the bobbin 110 so that the indicia are successively displayed as the spool 5134 is rotated or advanced. In FIGS. 23 and 24 the wavelike engagement surface 300 of the bobbin 110 is not shown for the purposes of clarity.

The spool 134 is arranged to rotate upon movement of the yokes 566, 568 to effect delivery of a dose of medicament from reservoir 514, such that the number on the ribbon 5128 is advanced to indicate that another dose has been dispensed by the inhaler 510. The ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase or

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decrease upon rotation of the spool **5134**. For example, the ribbon **5128** can be arranged such that the numbers, or other suitable indicia, decrease upon rotation of the spool **5134** to indicate the number of doses remaining in the inhaler **510**. Alternatively, the ribbon **5128** can be arranged such that the numbers, or other suitable indicia, increase upon rotation of the spool **5134** to indicate the number of doses dispensed by the inhaler **10**.

The indexing spool **5134** includes radially extending teeth **5136**, which are engaged by pawl **5138** extending from a cam follower **578** of the second yoke **568** upon movement of the yoke to rotate, or advance, the indexing spool **5134**. More particularly, the pawl **5138** is shaped and arranged such that it engages the teeth **5136** and advances the indexing spool **5134** only upon the mouthpiece cover **528** being closed and the yokes **566**, **568** moved back towards the cap **526** of the housing **518**.

The dose counting system **516** also includes a chassis **5140** that secures the dose counting system to the hopper **542** and includes shafts **108**, **5144** for receiving the bobbin **110** and the indexing spool **5134**. As described above with reference to FIGS. **1** to **20**, the bobbin shaft **108** is forked and includes radially nubs **5146** for creating a resilient resistance to rotation of the bobbin **110** on the shaft **108** by engaging with the wavelike engagement surface **300** inside the bobbin **110**. A clutch spring **5148** is received on the end of the indexing spool **5134** and locked to the chassis **5140** to allow rotation of the spool **5134** in only a single direction.

Various modifications may be made to the embodiment shown without departing from the scope of the invention as defined by the accompanying claims as interpreted under patent law.

What is claimed:

1. An inhaler for metered dose inhalation, the inhaler comprising:

- a main body having a canister housing,
- a medicament canister, which is moveable relative to the canister housing and retained in a central outlet port of the canister housing arranged to mate with a canister fire stem of the medicament canister, and

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a dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of the medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall, and wherein the canister housing has a longitudinal axis X which passes through the center of the central outlet port,

the inner wall canister support formation, the actuation member, and the central outlet port lying in a common plane coincident with the longitudinal axis X.

2. The inhaler as claimed in claim **1** wherein the medicament canister is movable relative to the dose counter.

3. The inhaler as claimed in claim **1** further comprising an aperture formed in the inner wall through which the portion of the actuation member extends.

4. The inhaler as claimed in claim **1**, wherein the first inner wall canister support formation comprises a support rail which extends longitudinally along an inside surface of the main body.

5. The inhaler as claimed in claim **4**, wherein the support rail includes a step formed thereon.

6. The inhaler as claimed in claim **4** further comprising a plurality of support rails each of which extends longitudinally along an inside surface of the main body.

7. The inhaler as claimed in claim **6**, wherein two of the plurality of support rails are positioned at opposite ends of the inside surface of the main body to face each other.

8. The inhaler as claimed in claim **4**, wherein the support rail includes two steps formed thereon, the steps being spaced apart longitudinally along an inside surface of the main body.

9. The inhaler as claimed in claim **4**, wherein the support rail merges with the inner wall at a location adjacent the aperture.

10. The inhaler as claimed in claim **9**, wherein a width dimension of the support rail is not constant, and the width dimension is greatest at the location where the support rail merges with the inner wall.

\* \* \* \* \*

## **EXHIBIT 2**



U 8079874



# THE UNITED STATES OF AMERICA

**TO ALL TO WHOM THESE PRESENTS SHALL COME:**

**UNITED STATES DEPARTMENT OF COMMERCE**

**United States Patent and Trademark Office**

February 26, 2021

**THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM  
THE RECORDS OF THIS OFFICE OF:**

**U.S. PATENT: 9,808,587**

**ISSUE DATE: November 07, 2017**

**By Authority of the**

**Under Secretary of Commerce for Intellectual Property  
and Director of the United States Patent and Trademark Office**



**P. R. GRANT**  
**Certifying Officer**

(12) **United States Patent**  
**Walsh et al.**

(10) **Patent No.:** **US 9,808,587 B2**

(45) **Date of Patent:** **\*Nov. 7, 2017**

(54) **DOSE COUNTER FOR INHALER HAVING  
AN ANTI-REVERSE ROTATION ACTUATOR**

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Uschold**, Leominster, MA (US); **Jeffrey  
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(73) Assignees: **IVAX PHARMACEUTICALS  
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LIMITED** (IE)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 0 days.  
  
This patent is subject to a terminal dis-  
claimer.

(21) Appl. No.: **15/269,249**

(22) Filed: **Sep. 19, 2016**

(65) **Prior Publication Data**  
US 2017/0000962 A1 Jan. 5, 2017

#### **Related U.S. Application Data**

(60) Continuation of application No. 14/103,324, filed on  
Dec. 11, 2013, now Pat. No. 9,463,289, which is a  
(Continued)

(51) **Int. Cl.**  
**G06M 1/06** (2006.01)  
**A61M 11/00** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **A61M 15/0078** (2014.02); **A61M 11/00**  
(2013.01); **A61M 15/009** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
USPC ..... 235/8, 103; 128/200.23  
See application file for complete search history.

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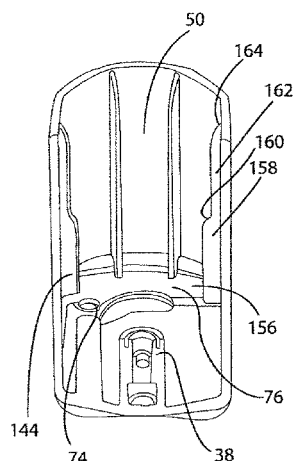
*Primary Examiner* — Daniel Hess

(74) *Attorney, Agent, or Firm* — Morgan, Lewis &  
Bockius LLP

(57) **ABSTRACT**

An inhaler includes a main body having a canister housing,  
a medicament canister retained in a central outlet port of the  
canister housing, and a dose counter having an actuation  
member for operation by movement of the medicament  
canister. The canister housing has an inner wall, and a first  
inner wall canister support formation extending inwardly  
from a main surface of the inner wall. The canister housing

(Continued)





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has a longitudinal axis X which passes through the center of the central outlet port. The first inner wall canister support formation, the actuation member, and the central outlet port lie in a common plane coincident with the longitudinal axis X such that the first inner wall canister support formation protects against unwanted actuation of the dose counter by reducing rocking of the medicament canister relative to the main body of the inhaler.

## 22 Claims, 17 Drawing Sheets

### Related U.S. Application Data

division of application No. 13/110,532, filed on May 18, 2011, now Pat. No. 8,978,966.

- (60) Provisional application No. 61/417,659, filed on Nov. 29, 2010, provisional application No. 61/345,763, filed on May 18, 2010.

### (51) Int. Cl.

*A61M 15/00* (2006.01)

*G06M 1/24* (2006.01)

### (52) U.S. Cl.

CPC .... *A61M 15/0025* (2014.02); *A61M 15/0026* (2014.02); *A61M 15/0065* (2013.01); *A61M 15/0071* (2014.02); *G06M 1/246* (2013.01); *A61M 2202/064* (2013.01); *A61M 2205/6063* (2013.01); *A61M 2207/00* (2013.01); *A61M 2207/10* (2013.01); *Y10T 29/49* (2015.01); *Y10T 29/49764* (2015.01); *Y10T 29/49826* (2015.01)

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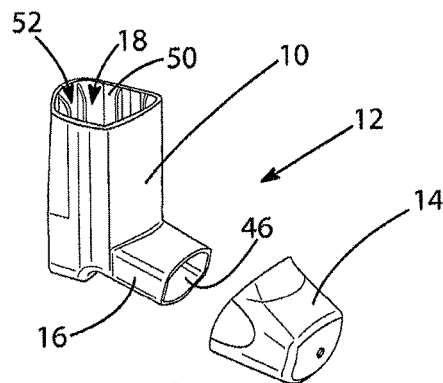


FIG. 1

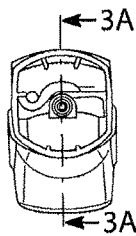


FIG. 2

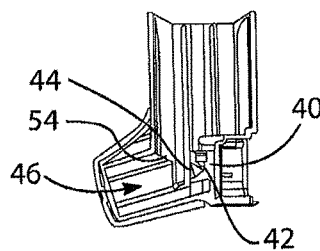


FIG. 3A

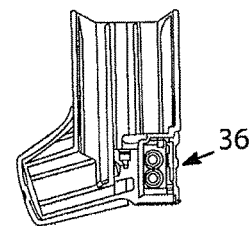


FIG. 3B

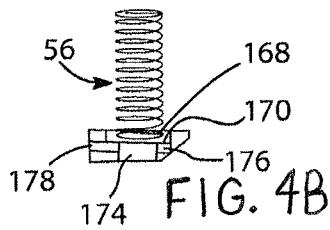


FIG. 4B

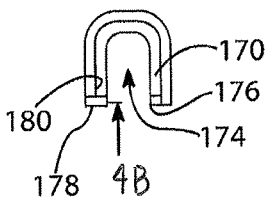


FIG. 4C

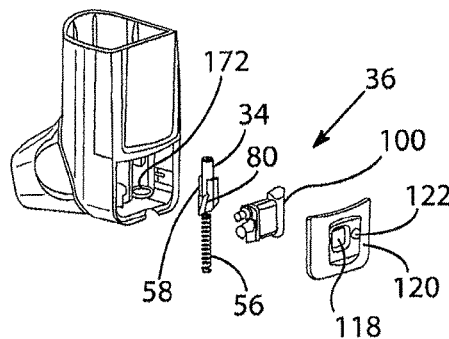


FIG. 4A

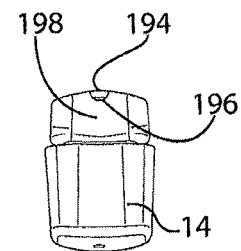


FIG. 5

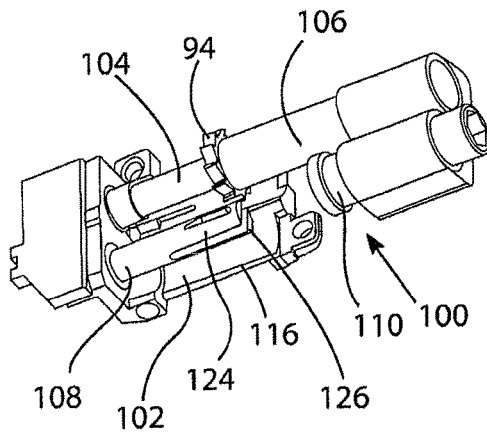


FIG. 6A

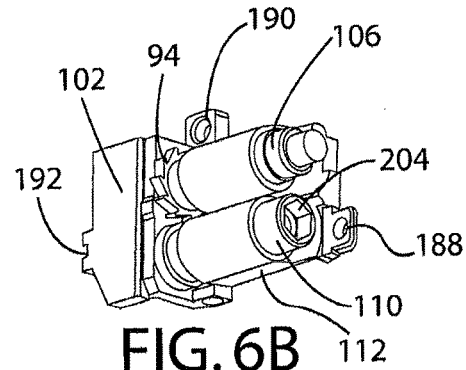


FIG. 6B

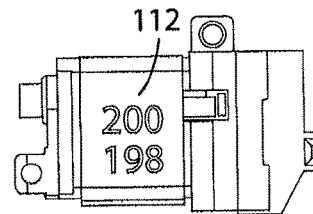


FIG. 6C

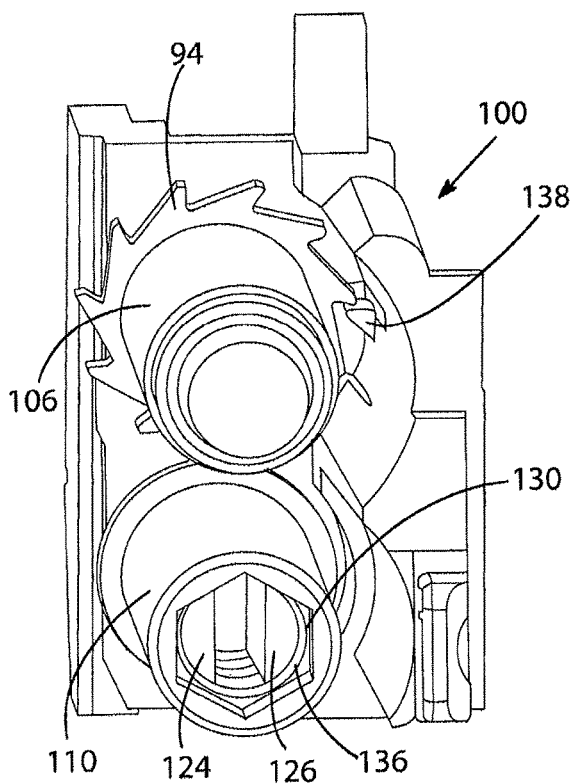


FIG. 6D

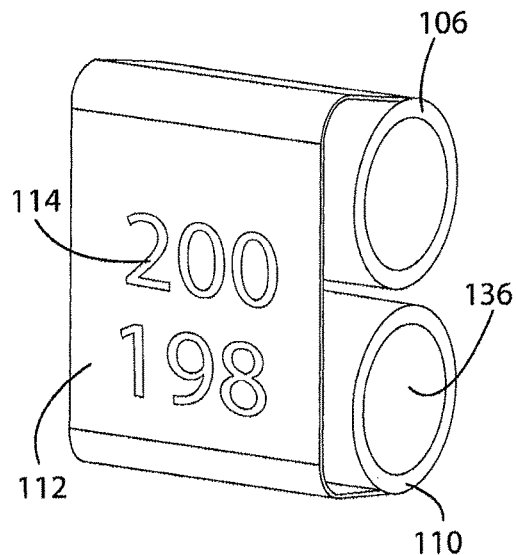


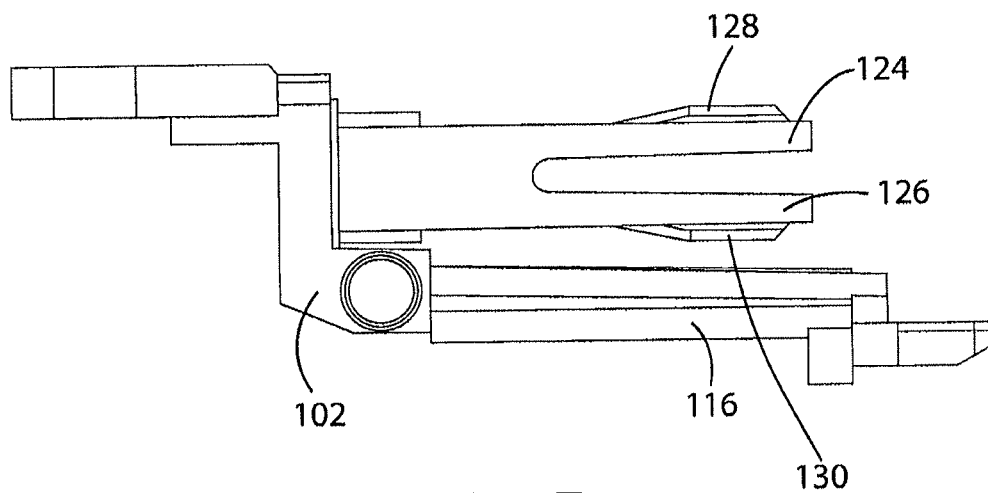
FIG. 6E

**U.S. Patent**

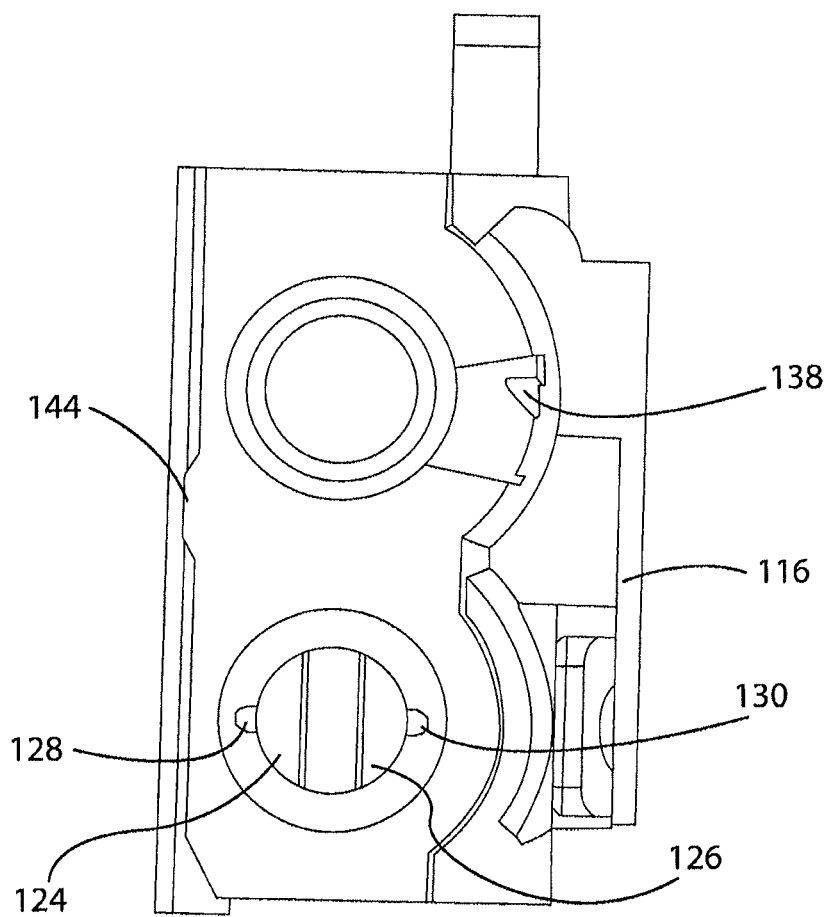
**Nov. 7, 2017**

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**FIG. 6F**



**FIG. 6G**

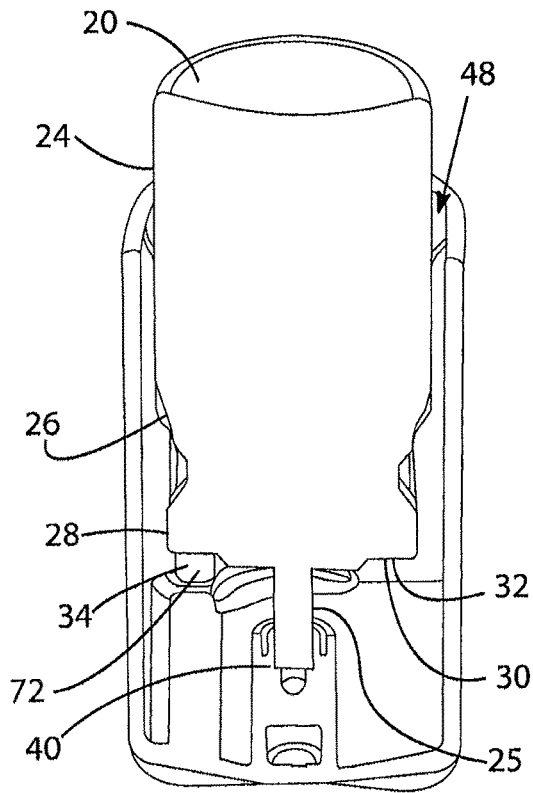


FIG. 7A

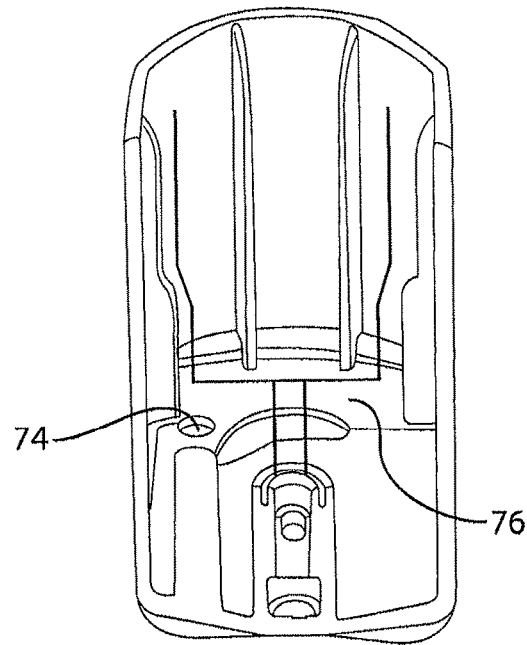


FIG. 7B

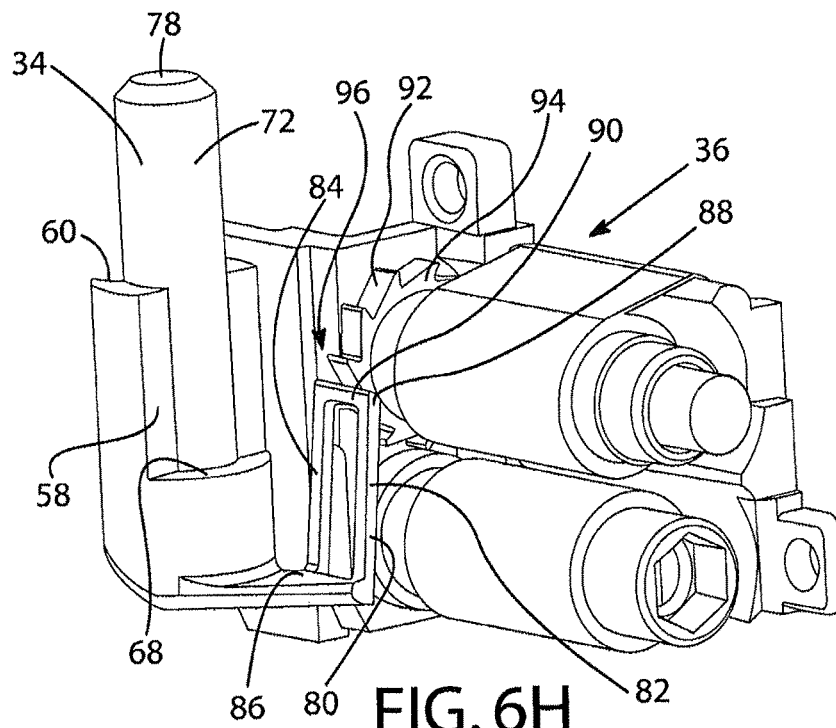


FIG. 6H

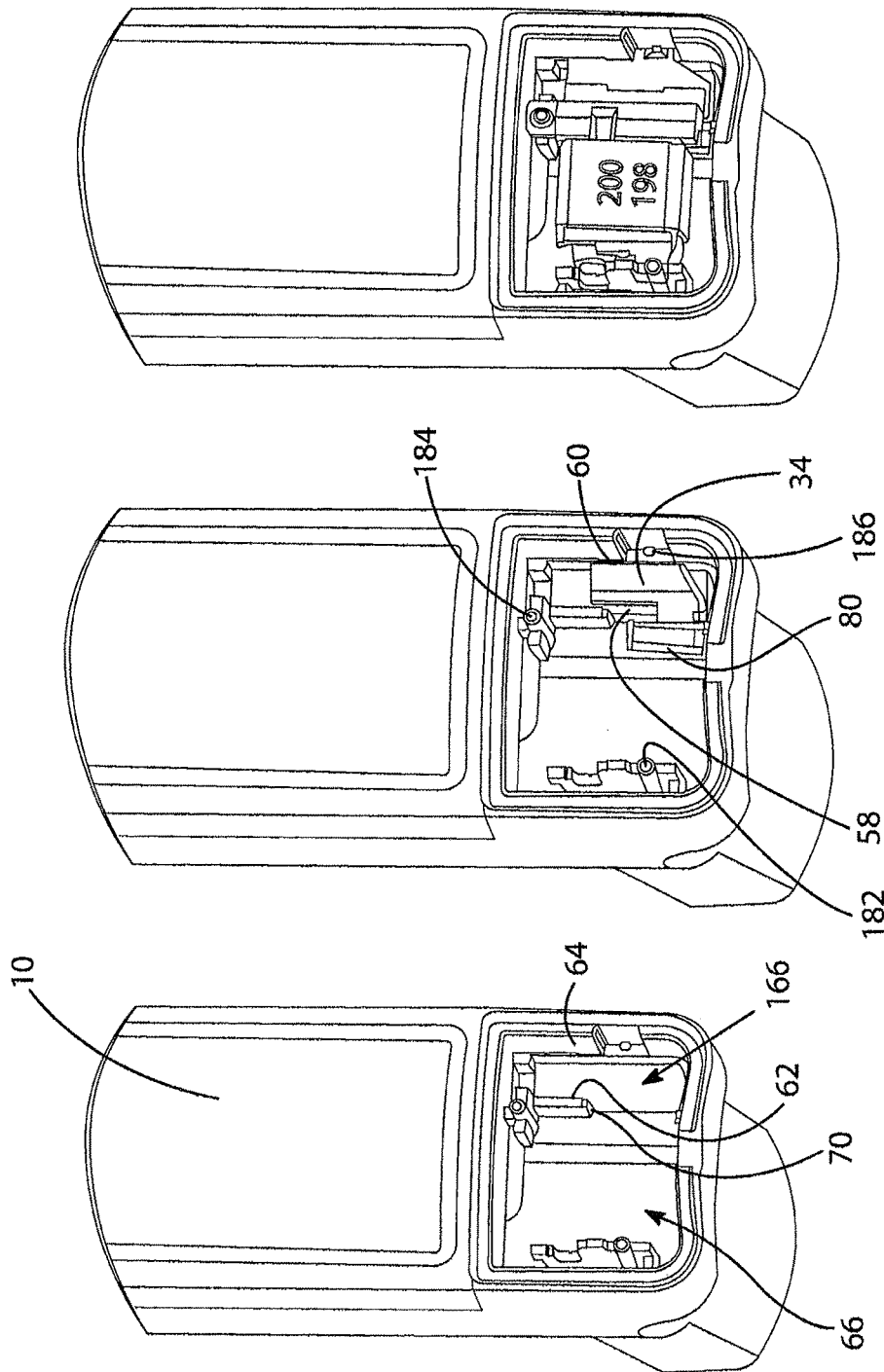


FIG. 8C

FIG. 8B

FIG. 8A

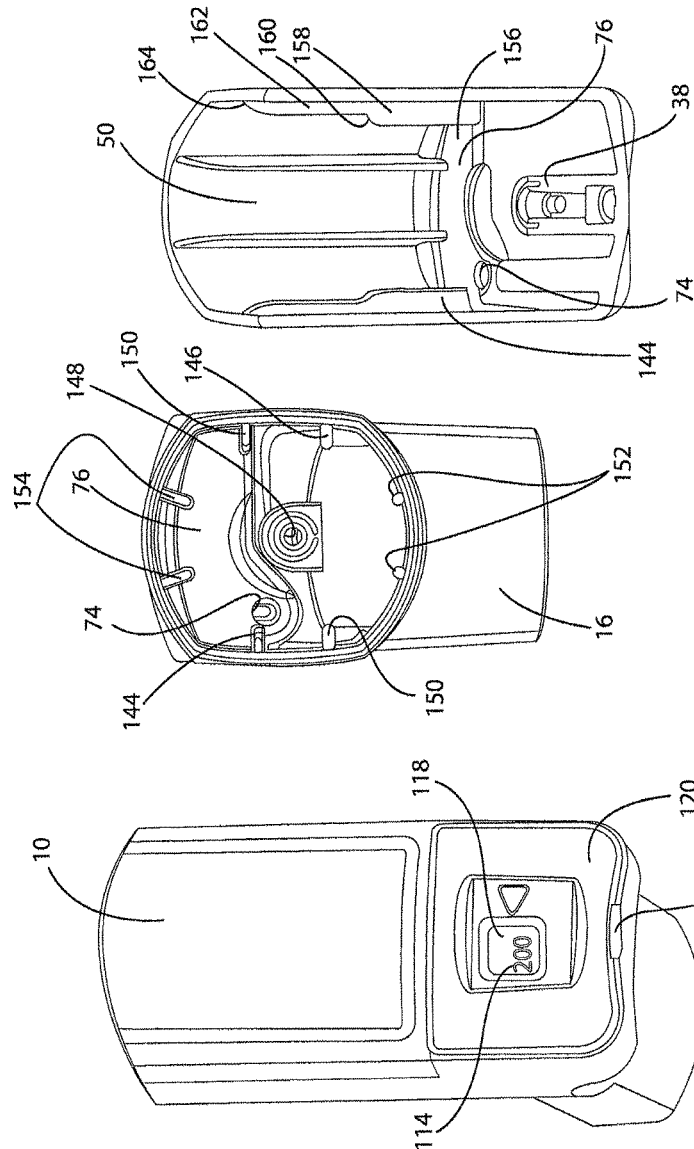


FIG. 7C

FIG. 7D

FIG. 8D



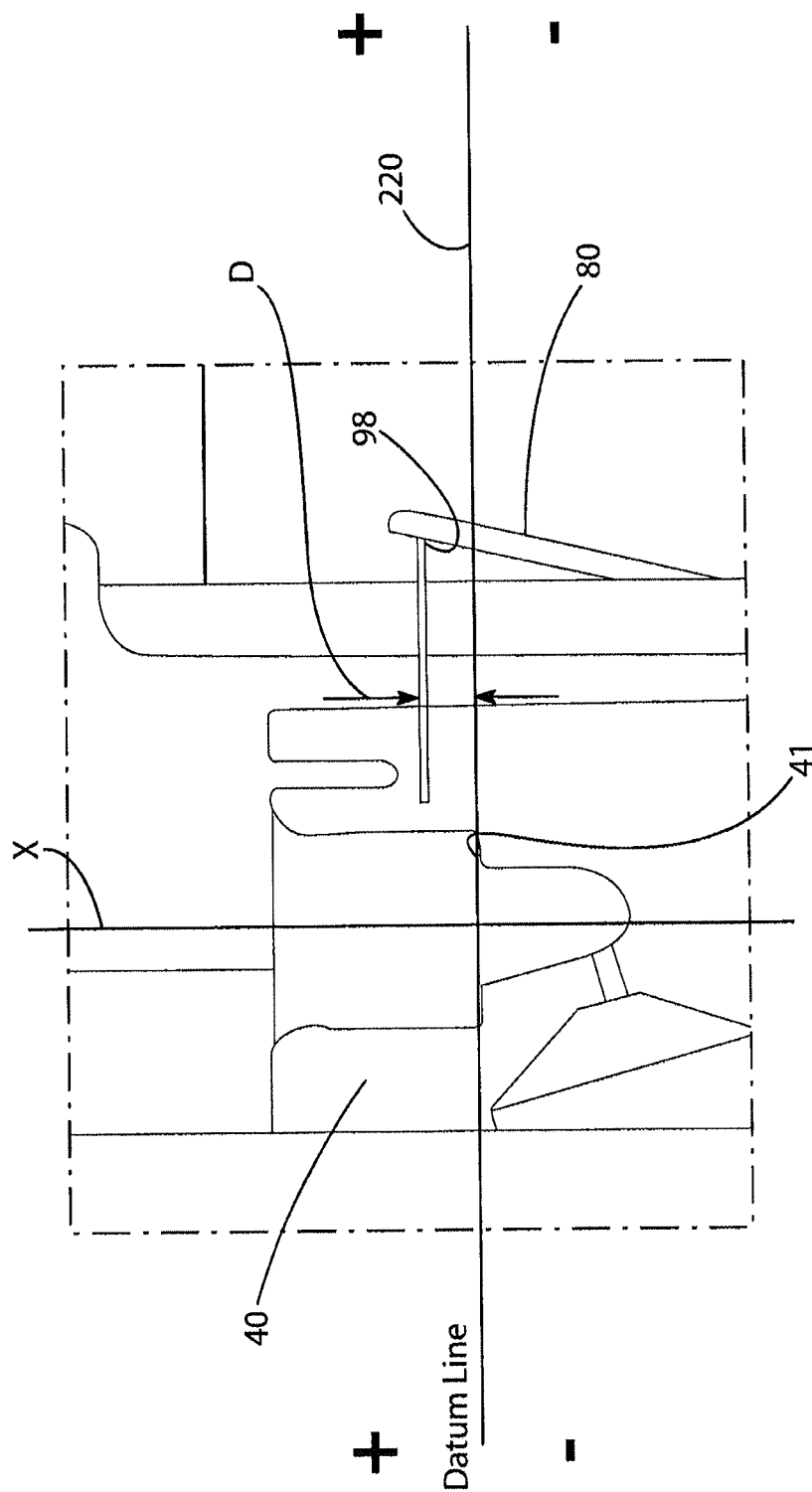


FIG. 9

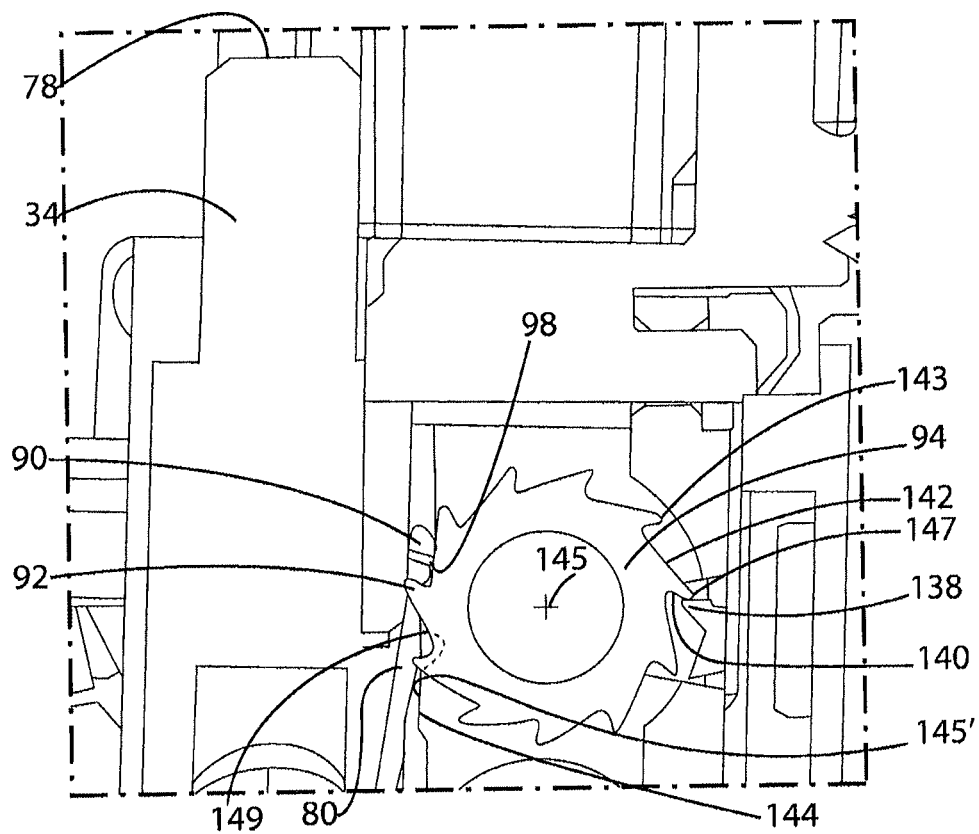
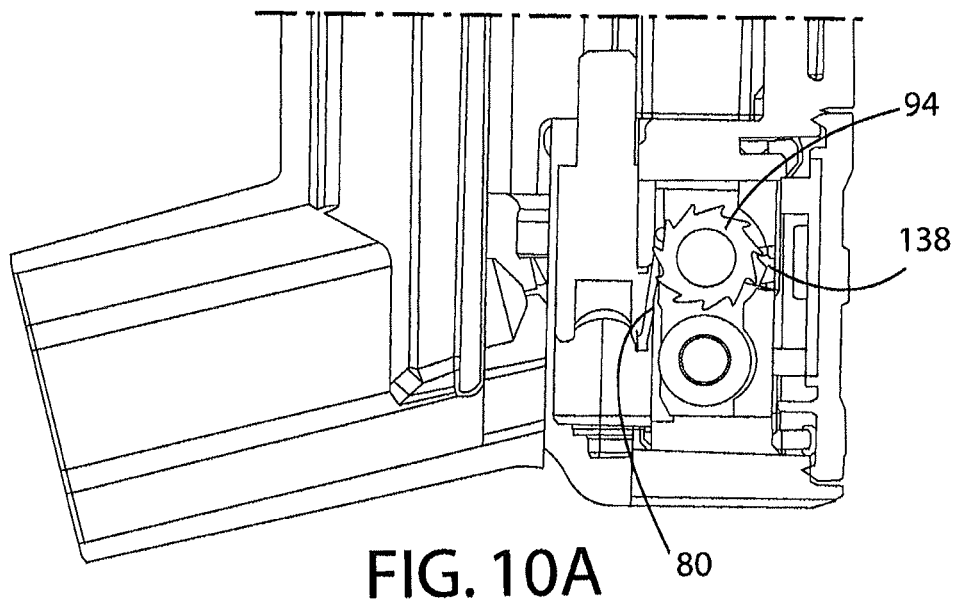


FIG. 10B

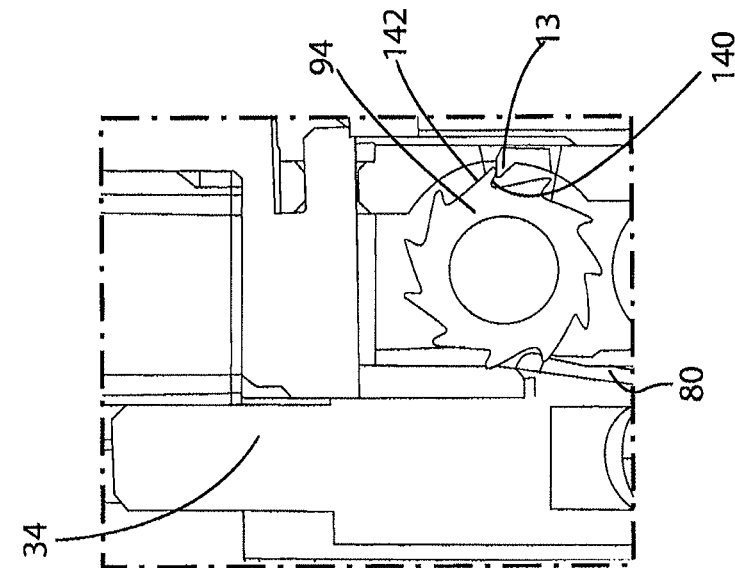


FIG. 10E

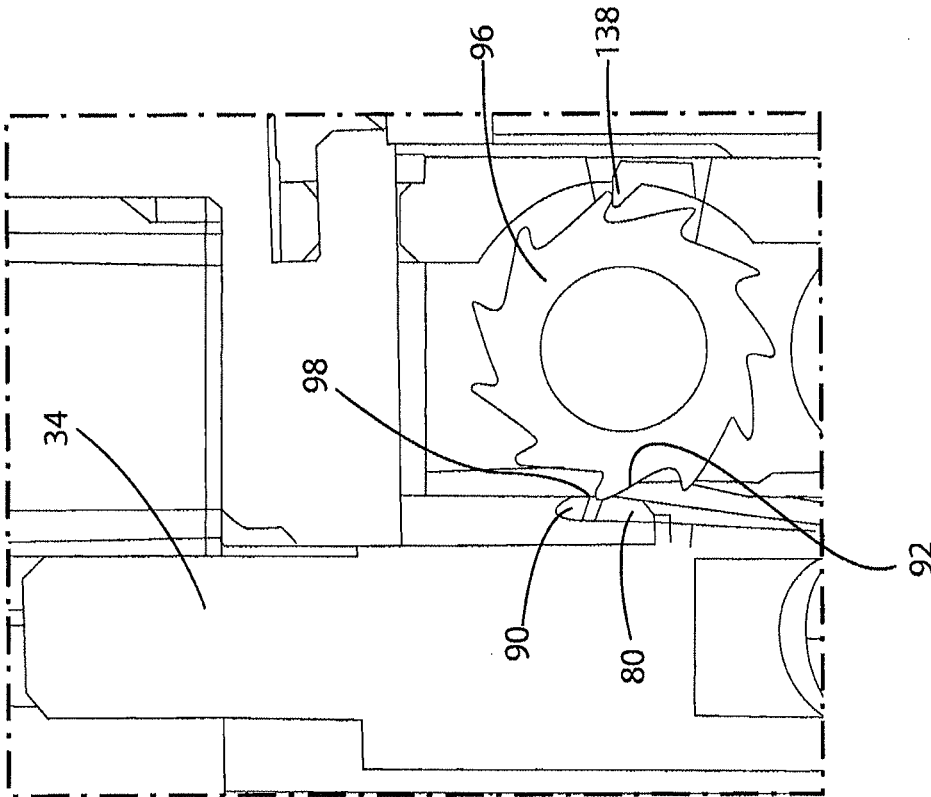


FIG. 10C

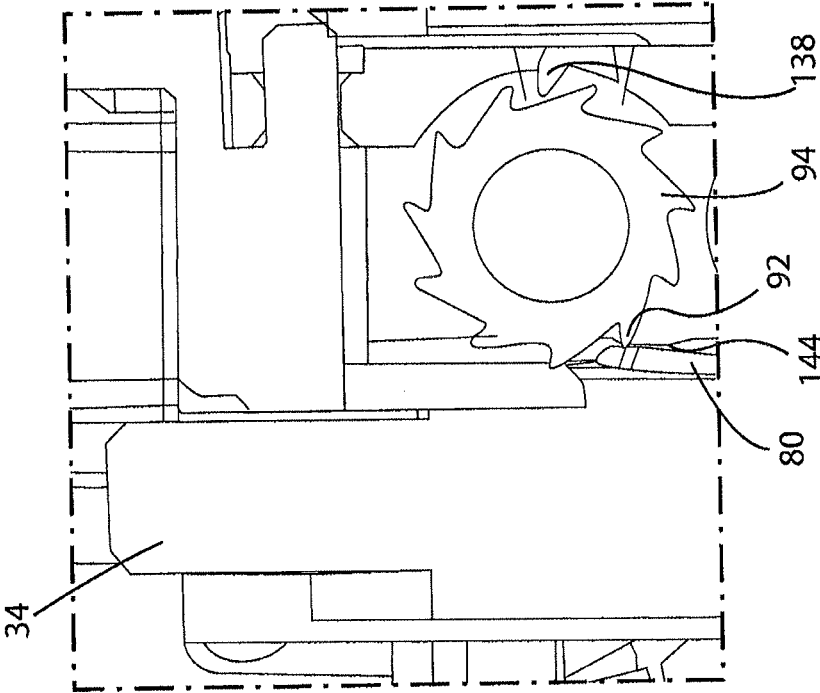


FIG. 10F

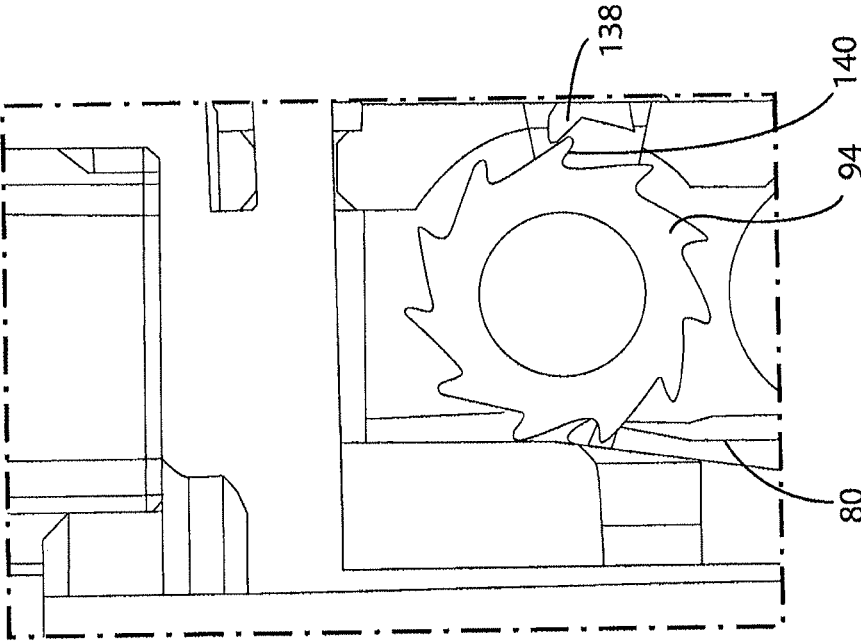


FIG. 10D

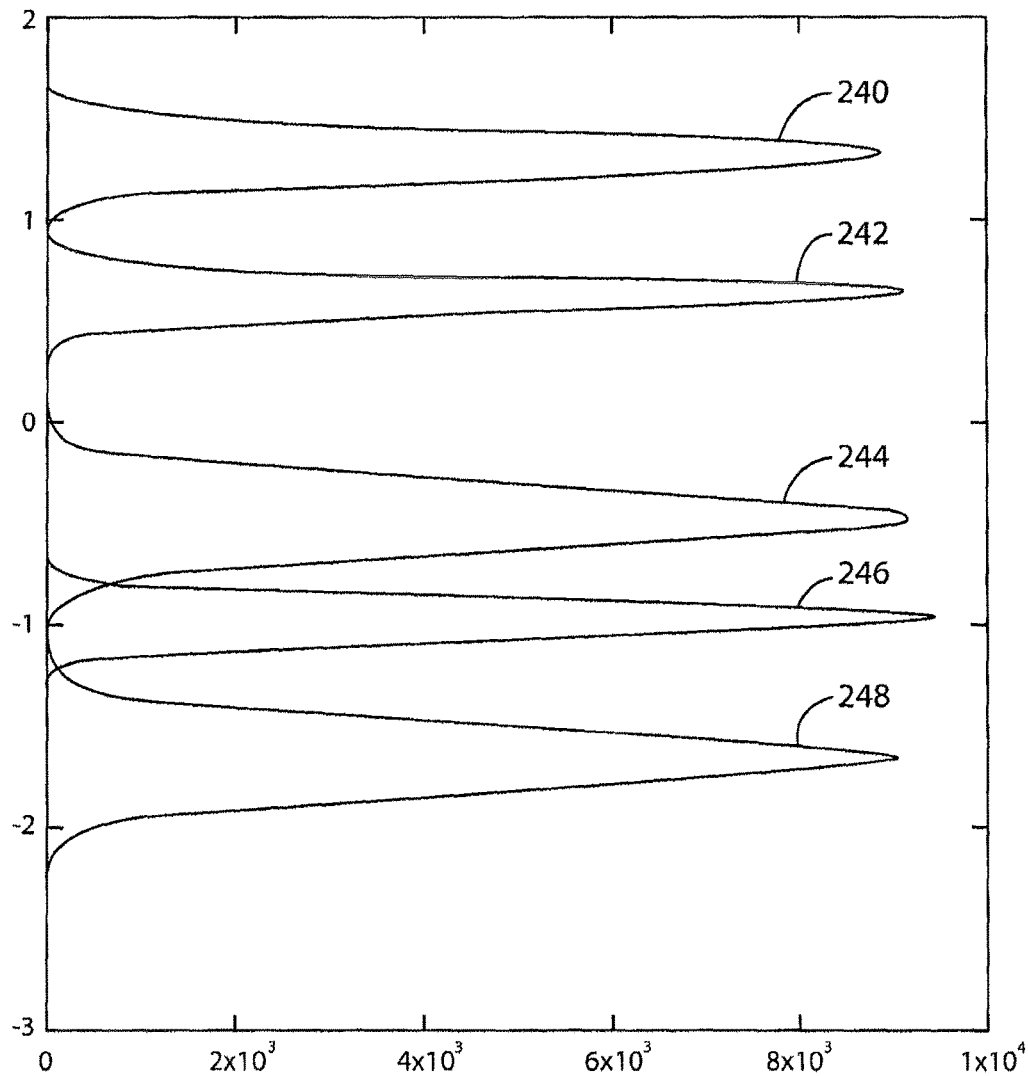


FIG. 11

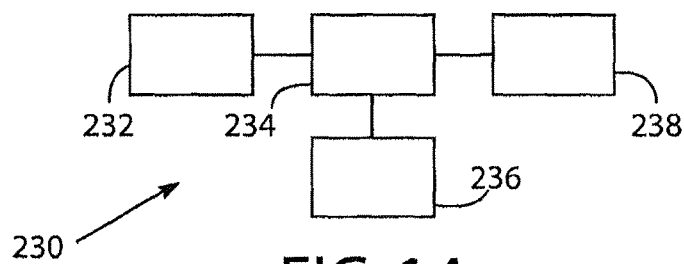


FIG. 14

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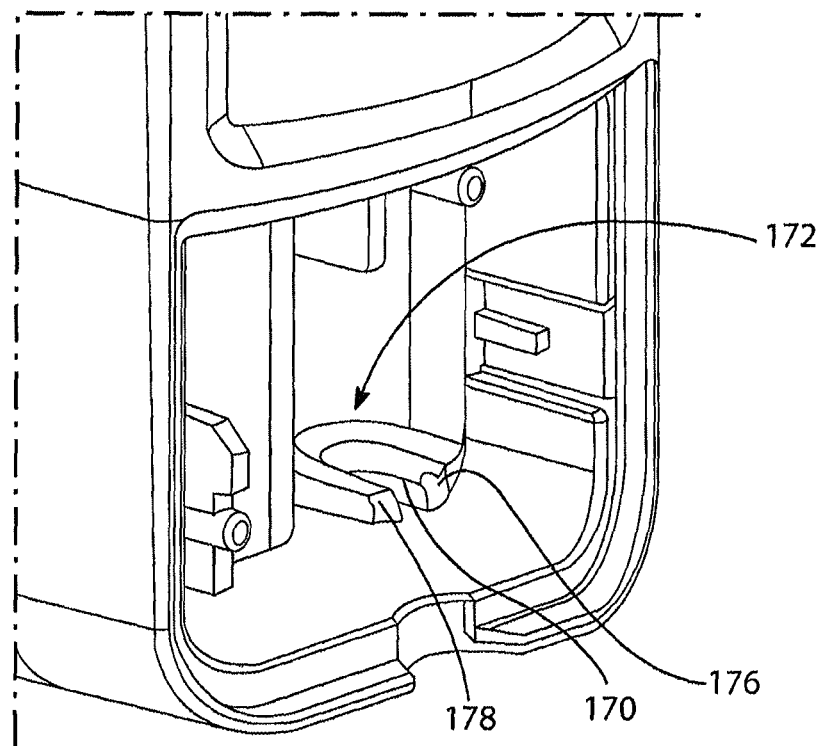


FIG. 12

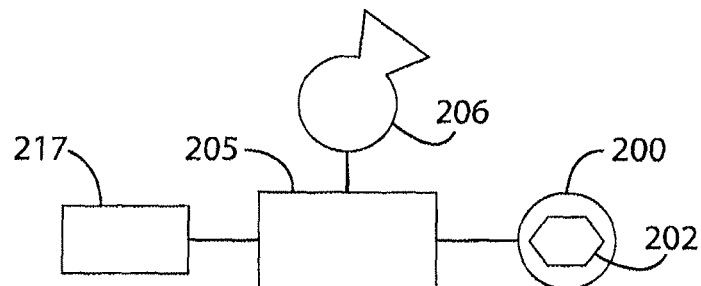
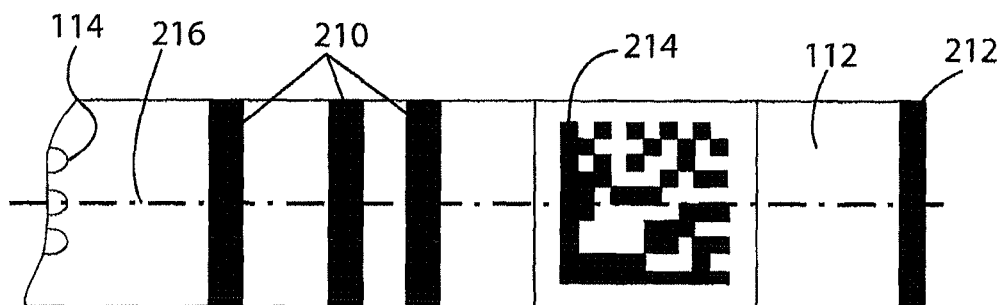


FIG. 13

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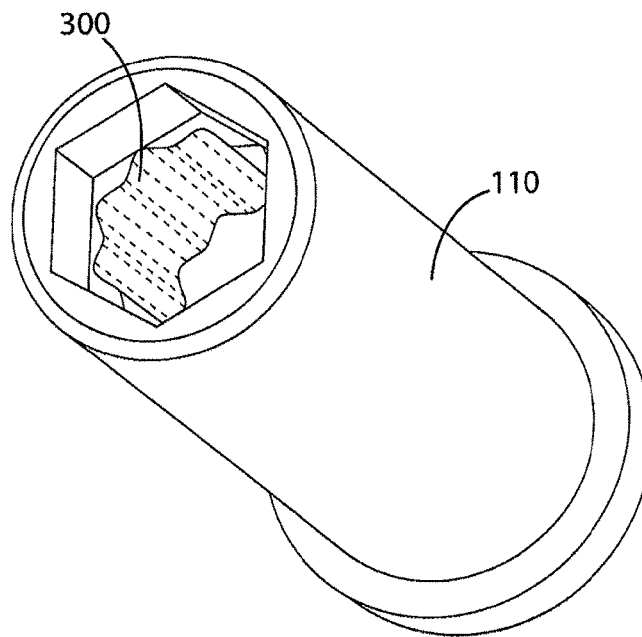


FIG. 15

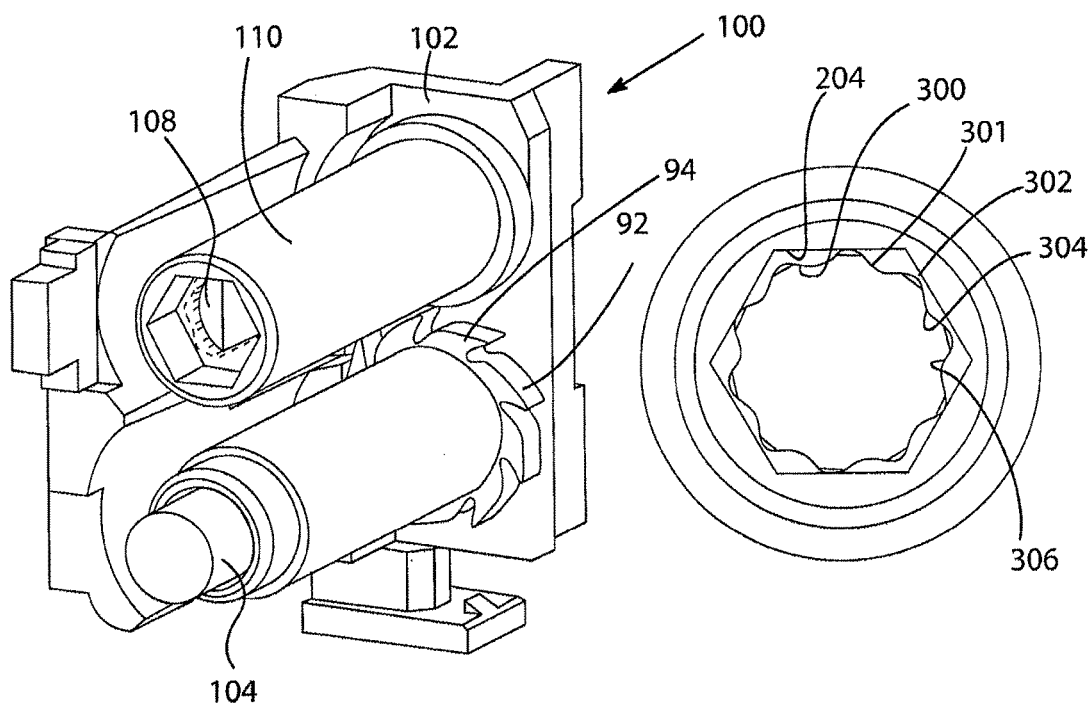


FIG. 20

FIG. 16

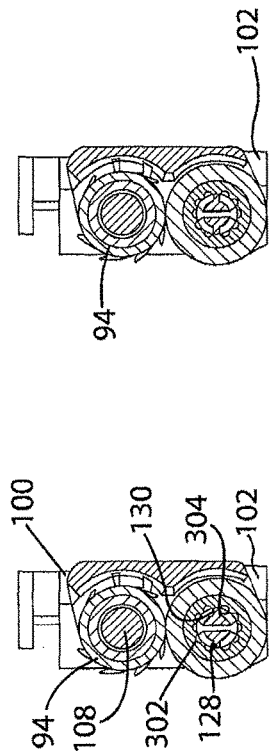


FIG. 18A

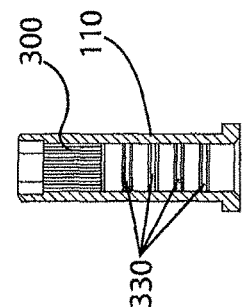


FIG. 17

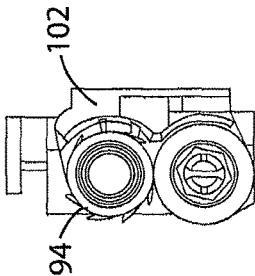


FIG. 18B

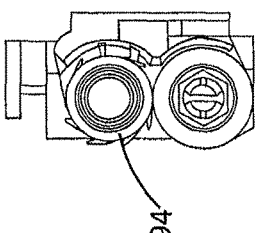


FIG. 19A

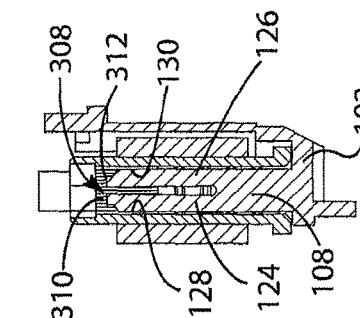


FIG. 18C

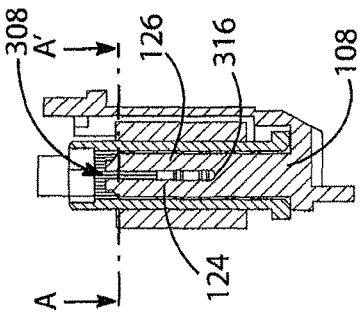


FIG. 19B

FIG. 19C



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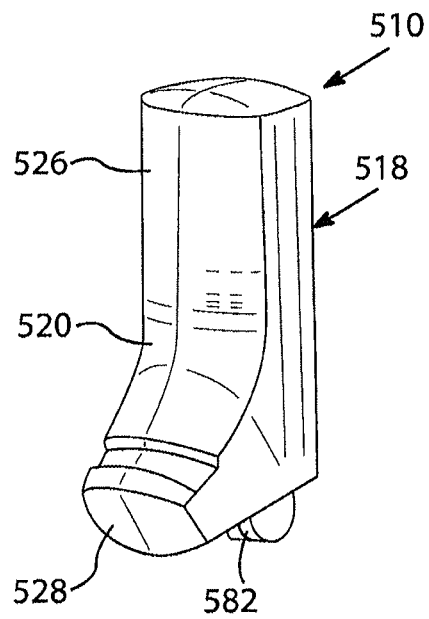


FIG. 21

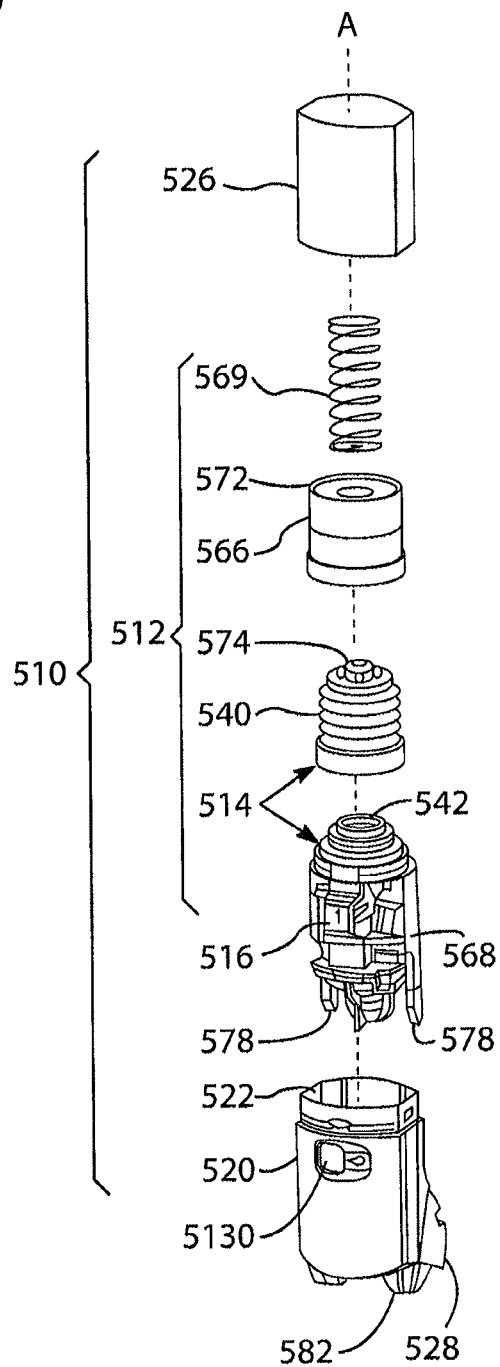


FIG. 22

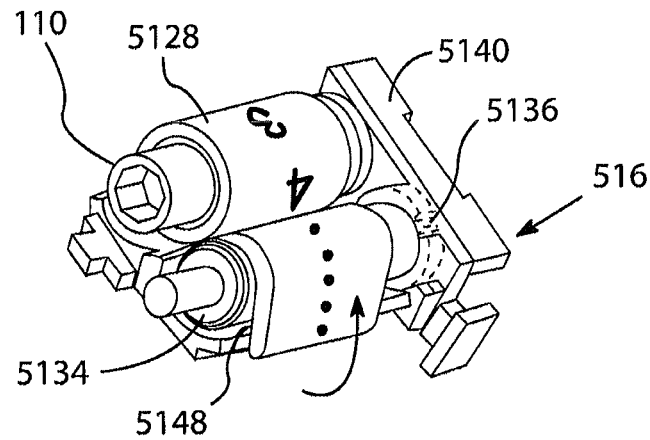


FIG. 23

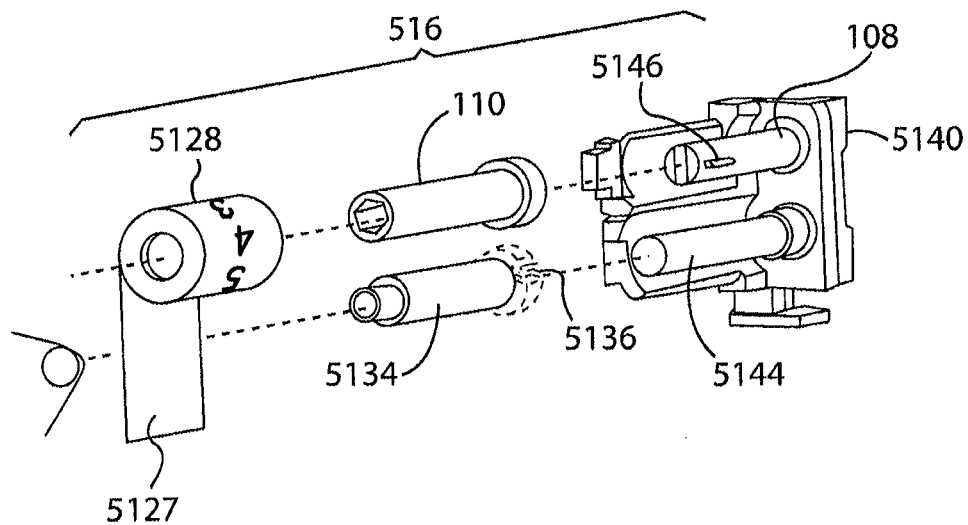


FIG. 24

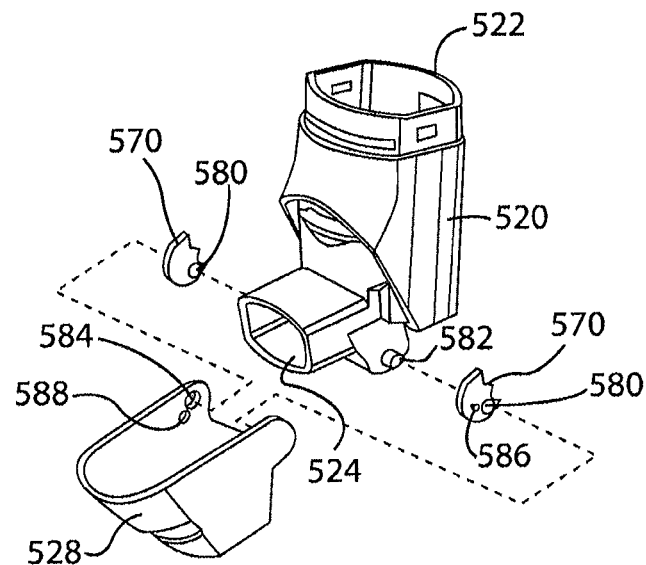


FIG. 25

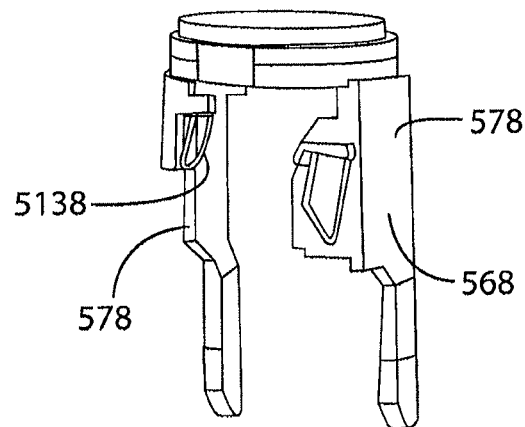


FIG. 26

US 9,808,587 B2

1

## DOSE COUNTER FOR INHALER HAVING AN ANTI-REVERSE ROTATION ACTUATOR

### CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is a continuation patent application of U.S. Non-Provisional patent application Ser. No. 14/103,324, filed Dec. 11, 2013, which is a divisional patent application of U.S. Non-Provisional patent application Ser. No. 13/110,532, filed May 18, 2011, now U.S. Pat. No. 8,978,966, issued Mar. 17, 2015, which claims priority to U.S. Provisional Patent Application No. 61/345,763, filed May 18, 2010, and U.S. Provisional Patent Application No. 61/417,659, filed Nov. 29, 2010, each of which is incorporated herein by reference in its entirety for any and all purposes.

### FIELD OF THE INVENTION

The present invention relates to dose counters for inhalers, inhalers and methods of assembly thereof. The invention is particularly applicable to metered dose inhalers including dry power medicament inhalers, breath actuated inhalers and manually operated metered dose medicament inhalers.

### BACKGROUND OF THE INVENTION

Metered dose inhalers can comprise a medicament-containing pressurised canister containing a mixture of active drug and propellant. Such canisters are usually formed from a deep-drawn aluminium cup having a crimped lid which carries a metering valve assembly. The metering valve assembly is provided with a protruding valve stem which, in use is inserted as a push fit into a stem block in an actuator body of an inhaler having a drug delivery outlet. In order to actuate a manually operable inhaler, the user applies by hand a compressive force to a closed end of the canister and the internal components of the metering valve assembly are spring loaded so that a compressive force of approximately 15 to 30 N is required to activate the device in some typical circumstances.

In response to this compressive force the canister moves axially with respect to the valve stem and the axial movement is sufficient to actuate the metering valve and cause a metered quantity of the drug and the propellant to be expelled through the valve stem. This is then released into a mouthpiece of the inhaler via a nozzle in the stem block, such that a user inhaling through the outlet of the inhaler will receive a dose of the drug.

A drawback of self-administration from an inhaler is that it is difficult to determine how much active drug and/or propellant are left in the inhaler, if any, especially of the active drug and this is potentially hazardous for the user since dosing becomes unreliable and backup devices not always available.

Inhalers incorporating dose counters have therefore become known.

WO 98/028033 discloses an inhaler having a ratchet mechanism for driving a tape drive dose counter. A shaft onto which tape is wound has a friction clutch or spring for restraining the shaft against reverse rotation.

EP-A-1486227 discloses an inhaler for dry powered medicament having a ratchet mechanism for a tape dose counter which is operated when a mouthpiece of the inhaler is closed. Due to the way in which the mouthpiece is opened and closed, and actuation pawl of the device which is

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mounted on a yoke, travels a known long stroke of consistent length as the mouthpiece is opened and closed.

WO 2008/119552 discloses a metered-dose inhaler which is suitable for breath-operated applications and operates with a known and constant canister stroke length of 3.04 mm+/-0.255 mm. A stock bobbin of the counter, from which a tape is unwound, rotates on a shaft having a split pin intended to hold the stock bobbin taut. However, some dose counters do not keep a particularly reliable count, such as if they are dropped onto a hard surface.

More recently, it has become desirable to improve dose counters further and, in particular, it is felt that it would be useful to provide extremely accurate dose counters for manually-operated canister-type metered dose inhalers. Unfortunately, in these inhalers, it has been found in the course of making the present invention that the stroke length of the canister is to a very large extent controlled on each dose operation by the user, and by hand. Therefore, the stroke length is highly variable and it is found to be extremely difficult to provide a highly reliable dose counter for these applications. The dose counter must not count a dose when the canister has not fired since this might wrongly indicate to the user that a dose has been applied and if done repeatedly the user would throw away the canister or whole device before it is really time to change the device due to the active drug and propellant reaching a set minimum. Additionally, the canister must not fire without the dose counter counting because the user may then apply another dose thinking that the canister has not fired, and if this is done repeatedly the active drug and/or propellant may run out while the user thinks the device is still suitable for use according to the counter. It has also been found to be fairly difficult to assembly some known inhaler devices and the dose counters therefor. Additionally, it is felt desirable to improve upon inhalers by making them easily usable after they have been washed with water.

The present invention aims to alleviate at least to a certain extent one or more of the problems of the prior art.

### SUMMARY OF THE INVENTION

According to a first aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a counter display arranged to indicate dosage information, a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input, wherein a regulator is provided which is arranged to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

The regulator is advantageous in that it helps prevent unwanted motion of the counter display if the counter is dropped.

According to a further aspect of the present invention, the regulator provides a resistance force of greater than 0.1 N against movement of the counter display. According to still a further aspect of the present invention, the resistance force is greater than 0.3 N. According to yet a further aspect of the present invention, the resistance force is from 0.3 to 0.4 N.

Preferably, the counter comprises a tape.

Preferably, the tape has dose counter indicia displayed thereon. The first station may comprise a region of the dose counter where tape is held which is located before a display location, such as a display window, for the counter indicia.

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The first station may comprise a first shaft, the tape being arranged on the first shaft and to unwind therefrom upon movement of the counter display.

The first shaft may be mounted for rotation relative to a substantially rotationally fixed element of the dose counter.

The regulator may comprise at least one projection which is arranged on one of the first shaft and the substantially rotationally fixed element and to engage incrementally with one or more formations on the other of the first shaft and the substantially rotationally fixed element.

At least two said projections may be provided. Exactly two said projections may be provided.

Each projection may comprise a radiused surface.

The at least one projection may be located on the substantially fixed element which may comprise a fixed shaft which is fixed to a main body of the dose counter, the first shaft being rotationally mounted to the fixed shaft.

Preferably, the fixed shaft has at least two resiliently flexible legs (or forks). Each leg may have at least one said projection formed in an outwardly facing direction thereon, said one or more formations being formed on an inwardly facing engagement surface of the first shaft, said at least one projection being arranged to resiliently engage said one or more formations. Preferably, a series of said formations are provided. An even number of said formations may be provided. Eight to twelve of said formations may be provided. In one embodiment, ten said formations are provided.

Each said formation may comprise a concavity formed on an engagement surface. Each concavity may comprise a radiused surface wall portion which preferably merges on at least one side thereof into a flat wall portion surface. The engagement surface may include a series of said concavities, and convex wall portions of the engagement surface may be formed between each adjacent two said concavities, each said convex wall portion comprising a convex radiused wall portion.

Each convex radiused wall portion of each convex wall portion may be connected by said flat wall portion surfaces to each adjacent concavity.

The fixed shaft may comprise a split pin with fork legs and each projection may be located on a said fork leg.

The first shaft may comprise a substantially hollow bobbin.

Said at least one formation may be located on an inner surface of the bobbin. In other embodiments it may be located on an outer surface thereof. Said engagement surface may extend partially along said bobbin, a remainder of the respective inner or outer surface having a generally smooth journal portion along at least a portion thereof.

The drive system may comprise a tooth ratchet wheel arranged to act upon a second shaft which is located at the second station, the second shaft being rotatable to wind the tape onto the second shaft.

The second shaft may be located on a main body of the dose counter spaced from and parallel to the first shaft.

The ratchet wheel may be fixed to the second shaft is arranged to rotate therewith. The ratchet wheel may be secured to an end of the second shaft and aligned coaxially with the second shaft.

The dose counter may include anti-back drive system which is arranged to restrict motion of the second shaft. The anti-back drive system may include a substantially fixed tooth arranged to act upon teeth of the ratchet wheel.

According to a further aspect of the present invention, a dose counter includes an anti-back drive system which is arranged to restrict motion of the second shaft in a tape winding direction.

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According to a further aspect of the present invention there is provided a shaft for holding counter tape in a dose counter for an inhaler, the shaft having an engagement surface including incrementally spaced formations located around a periphery thereof, the formations comprising a series of curved concavities and convex portions.

The shaft may comprise a hollow bobbin.

The engagement surface may be a generally cylindrical inwardly directed surface.

The engagement surface may include a flat surface wall portion joining each concavity and convex wall portion.

Each concavity may comprise a radiused wall portion.

Each convex wall portion may comprise a radiused wall portion.

Said concavities may be regularly spaced around a longitudinal axis of the shaft.

Said convex wall portions may be regularly spaced around a longitudinal axis of the shaft.

In some embodiments there may be from eight to twelve said concavities and/or convex wall portions regularly spaced around a longitudinal axis thereof.

One embodiment includes ten said concavities and/or convex wall portions regularly spaced around a longitudinal axis of the shaft.

According to a further aspect of the present invention there is provided a shaft and counter tape assembly for use in a dose counter for an inhaler, the assembly comprising a rotatable shaft and a counter tape which is wound around the shaft and is adapted to unwind therefrom upon inhaler actuation, the shaft having an engagement surface which includes incrementally spaced formations located around a periphery thereof.

According to a further aspect of the present invention there is provided an inhaler for the inhalation of medication and the like, the inhaler including a dose counter as in the first aspect of the present invention.

A preferred construction consists of a manually operated metered dose inhaler including a dose counter chamber including a dose display tape driven by a ratchet wheel which is driven in turn by an actuator pawl actuated by movement of a canister, the tape unwinding from a stock bobbin during use of the inhaler, a rotation regulator being provided for the stock bobbin and comprising a wavelike engagement surface with concavities which engage against control elements in the form of protrusions on resilient forks of a split pin thereby permitting incremental unwinding of the stock bobbin yet resisting excessive rotation if the inhaler is dropped onto a hard surface.

According to another aspect of the present invention there is provided a dose counter for a metered dose inhaler having a body arranged to retain a medicament canister of predetermined configuration for movement of the canister relative thereto; the dose counter comprising: an incremental counting system for counting doses, the incremental counting system having a main body, an actuator arranged to be driven in response to canister motion and to drive an incremental output member in response to canister motion, the actuator and incremental output member being configured to have predetermined canister fire and count configurations in a canister fire sequence, the canister fire configuration being determined by a position of the actuator relative to a datum at which the canister fires medicament and the count configuration being determined by a position of the actuator relative to the datum at which the incremental count system makes an incremental count, wherein the actuator is

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arranged to reach a position thereof in the count configuration at or after a position thereof in the canister fire configuration.

This arrangement has been found to be highly advantageous since it provides an extremely accurate dose counter which is suitable for use with manually operated metered dose inhalers. It has been found that dose counters with these features have a failure rate of less than 50 failed counts per million full canister activation depressions. It has been found in the course of making the present invention that highly reliable counting can be achieved with the dose counter counting at or soon after the point at which the canister fires. It has been is covered by the present inventors that momentum and motion involved in firing the canister, and in some embodiments a slight reduction in canister back pressure on the user at the time of canister firing, can very reliably result in additional further motion past the count point.

The actuator and incremental counting system may be arranged such that the actuator is displaced less than 1 mm, typically 0.25 to 0.75 mm, more preferably about 0.4 to 0.6 mm, relative to the body between its location in the count and fire configurations, about 0.48 mm being preferred. The canister, which can move substantially in line with the actuator, can reliably move this additional distance so as to achieve very reliable counting.

The incremental count system may comprise a ratchet mechanism and the incremental output member may comprise a ratchet wheel having a plurality of circumferentially spaced teeth arranged to engage the actuator.

The actuator may comprise an actuator pawl arranged to engage on teeth of the ratchet wheel. The actuator pawl may be arranged to be connected to or integral with an actuator pin arranged to engage and be depressed by a medicament canister bottom flange. The actuator pawl may be generally U-shaped having two parallel arms arranged to pull on a central pawl member arranged substantially perpendicular thereto. This provides a very reliable actuator pawl which can reliably pull on the teeth of the ratchet wheel.

The incremental count system may include a tape counter having tape with incremental dose indicia located thereon, the tape being positioned on a tape stock bobbin and being arranged to unwind therefrom.

The actuator and incremental output member may be arranged to provide a start configuration at which the actuator is spaced from the ratchet output member, a reset configuration at which the actuator is brought into engagement with the incremental output member during a canister fire sequence, and an end configuration at which the actuator disengages from the ratchet output during a canister fire sequence.

The actuator may be arranged to be located about 1.5 to 2.0 mm, from its location in the fire configuration, when in the start configuration, about 1.80 mm being preferred.

The actuator may be arranged to be located about 1.0 to 1.2 mm, from its location in the fire configuration, when in the reset configuration, about 1.11 mm being preferred.

The actuator may be arranged to be located about 1.1 to 1.3 mm, from its location in the fire configuration, when in the end configuration, about 1.18 mm being preferred.

These arrangements provide extremely reliable dose counting, especially with manually operated canister type metered dose inhalers.

The main body may include a formation for forcing the actuator to disengage from the incremental output member when the actuator is moved past the end configuration. The formation may comprise a bumped up portion of an other-

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wise generally straight surface against which the actuator engages and along which it is arranged to slide during a canister firing sequence.

The dose counter may include a counter pawl, the counter pawl having a tooth arranged to engage the incremental output member, the tooth and incremental output member being arranged to permit one way only incremental relative motion therebetween. When the incremental output member comprises a ratchet wheel, the tooth can therefore serve as an anti-back drive tooth for the ratchet wheel, thereby permitting only one way motion or rotation thereof.

The counter pawl may be substantially fixedly mounted on the main body of the incremental count system and the counter pawl may be arranged to be capable of repeatedly engaging equi-spaced teeth of the incremental output member in anti-back drive interlock configurations as the counter is operated. The counter pawl may be positioned so that the incremental output member is halfway, or substantially halfway moved from one anti-back drive interlock configuration to the next when the actuator and incremental output member are in the end configuration thereof. This is highly advantageous in that it minimises the risk of double counting or non-counting by the dose counter.

According to a further aspect of the invention there is provided an inhaler comprising a main body arranged to retain a medicament canister of predetermined configuration and a dose counter mounted in the main body.

The inhaler main body may include a canister receiving portion and a separate counter chamber, the dose counter being located within the main body thereof, the incremental output member and actuator thereof inside the counter chamber, the main body of the inhaler having wall surfaces separating the canister-receiving portion and the counter chamber, the wall surfaces being provided with a communication aperture, an actuation member extending through the communication aperture to transmit canister motion to the actuator.

According to a further aspect of the present invention there is a provided an inhaler for metered dose inhalation, the inhaler comprising a main body having a canister housing arranged to retain a medicament canister for motion therein, and a dose counter, the dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of a medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation located directly adjacent the actuation member.

This is highly advantageous in that the first inner wall canister support formation can prevent a canister from rocking too much relative to the main body of the inhaler. Since the canister may operate the actuation member of the dose counter, this substantially improves dose counting and avoids counter errors.

The canister housing may have a longitudinal axis which passes through a central outlet port thereof, the central outlet port being arranged to mate with an outer canister fire stem of a medicament canister, the inner wall canister support formation, the actuation member and the outlet port lying in a common plane coincident with the longitudinal axis. Accordingly, this construction may prevent the canister from rocking towards the position of the dose counter actuation member, thereby minimising errors in counting.

The canister housing may have a further inner canister wall support formation located on the inner wall opposite, or substantially opposite, the actuation member. Accordingly, the canister may be supported against rocking motion away from the actuator member so as to minimise count errors.



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The canister housing may be generally straight and tubular and may have an arrangement in which each said inner wall support formation comprises a rail extending longitudinally along the inner wall.

Each said rail may be stepped, in that it may have a first portion located towards a medicine outlet end or stem block of the canister housing which extends inwardly a first distance from a main surface of the inner wall and a second portion located toward an opposite end of the canister chamber which extends inwardly a second, smaller distance from the main surface of the inner wall. This may therefore enable easy insertion of a canister into the canister housing such that a canister can be lined up gradually in step wise function as it is inserted into the canister housing.

The inhaler may include additional canister support rails which are spaced around an inner periphery of the inner wall of the canister housing and which extend longitudinally therealong.

At least one of the additional rails may extend a constant distance inwardly from the main surface of the inner wall.

At least one of the additional rails may be formed with a similar configuration to the first inner wall canister support formation.

The dose counter may, apart from said at least a portion of the actuation member, be located in a counter chamber separate from the canister housing, the actuation member comprising a pin extending through an aperture in a wall which separates the counter chamber and the canister housing.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicaments having: a body for retaining a medicament store; the body including a dose counter, the dose counter having a moveable actuator and a return spring for the actuator, the return spring having a generally cylindrical and annular end; the body having a support formation therein for supporting said end of the return spring, the support formation comprising a shelf onto which said end is engageable and a recess below the shelf.

This shelf and recess arrangement is highly advantageous since it allows a tool (such as manual or mechanical tweezers) to be used to place the return spring of the actuator onto the shelf with the tool then being withdrawn at least partially via the recess.

The shelf may be U-shaped.

The support formation may include a U-shaped upstanding wall extending around the U-shaped shelf, the shelf and upstanding wall thereby forming a step and riser of a stepped arrangement.

The recess below the shelf may also be U-shaped.

At least one chamfered surface may be provided at an entrance to the shelf. This may assist in inserting the actuator and return spring into position.

A further aspect of the invention provides a method of assembly of an inhaler which includes the step of locating said end of said spring on the shelf with an assembly tool and then withdrawing the assembly tool at least partly via the recess. This assembly method is highly advantageous compared to prior art methods in which spring insertion has been difficult and in which withdrawal of the tool has sometimes accidentally withdrawn the spring again.

The cylindrical and annular end of the spring may be movable in a direction transverse to its cylindrical extent into the shelf while being located thereon.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament, the inhaler having a body for retaining a medicament store; and

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a dose counter, the dose counter having a moveable actuator and a chassis mounted on the body; the chassis being heat staked in position on the body. This is highly advantageous in that the chassis can be very accurately positioned and held firmly in place, thereby further improving counting accuracy compared to prior art arrangements in which some movement of the chassis relative to the body may be tolerated in snap-fit connections.

The chassis may have at least one of a pin or aperture heat staked to a respective aperture or pin of the body.

The chassis may have a ratchet counter output member mounted thereon.

The ratchet counter output member may comprise a ratchet wheel arranged to reel in incrementally a dose meter tape having a dosage indicia located thereon.

According to a further aspect of the present invention there is provided a method of assembling an inhaler including the step of heat staking the chassis onto the body. The step of heat staking is highly advantageous in fixedly positioning the chassis onto the body in order to achieve highly accurate dose counting in the assembled inhaler.

The method of assembly may include mounting a spring-returned ratchet actuator in the body before heat staking the chassis in place. The method of assembly may include pre-assembling the chassis with a dose meter tape prior to the step of heat staking the chassis in place. The method of assembly may include attaching a dose meter cover onto the body after the heat staking step. The cover may be welded onto the body or may in some embodiments be glued or otherwise attached in place.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament and having a body, the body have a main part thereof for retaining a medicament store; and a dose counter, the dose counter being located in a dose counter chamber of the body which is separated from the main part of the body, the dose counter chamber of the body having a dosage display and being perforated so as to permit the evaporation of water or aqueous matter in the dose counter chamber into the atmosphere.

This is high advantageous since it enables the inhaler to be thoroughly washed and the dose counting chamber can thereafter dry out fully.

The display may comprise a mechanical counter display inside the dose counter chamber and a window for viewing the mechanical counter display. The mechanical counter display may comprise a tape. The perforated dose counter chamber may therefore enable reliable washing of the inhaler, if desired by the user, and may therefore dry out without the display window misting up.

The dose counter chamber may be perforated by a drain hole formed through an outer hole of the body. The drain hole may be located at a bottom portion of the body of the inhaler, thereby enabling full draining of the inhaler to be encouraged after washing when the inhaler is brought into an upright position.

According to a further aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a display tape arranged to be incrementally driven from a tape stock bobbin onto an incremental tape take-up drive shaft, the bobbin having an internal bore supported by and for rotation about a support shaft, at least one of the bore and support shaft having a protrusion which is resiliently biased into frictional engagement with the other of the bore and support shaft with longitudinally extending mutual frictional interaction. This arrangement may provide good friction for the bobbin, thereby improving tape counter



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display accuracy and preventing the bobbin from unwinding undesirably for example if the inhaler is accidentally dropped.

The support shaft may be forked and resilient for resiliently biasing the support shaft and bore into frictional engagement.

The support shaft may have two forks, or more in some cases, each having a radially extending protrusion having a friction edge extending therealong parallel to a longitudinal axis of the support shaft for frictionally engaging the bore of the support shaft with longitudinally extending frictional interaction therebetween.

The bore may be a smooth circularly cylindrical or substantially cylindrical bore.

Each of the above inhalers in accordance with aspects of the present invention may have a medicament canister mounted thereto.

The canister may comprise a pressurised metered dose canister having a reciprocally movable stem extending therefrom and movable into a main canister portion thereof for releasing a metered dose of medicament under pressure, for example by operating a metered dose valve inside the canister body. The canister may be operable by pressing by hand on the main canister body.

In cases in which one or more support rails or inner wall support formations are provided, the canister may at all times when within the canister chamber have a clearance of about 0.25 to 0.35 mm from the first inner wall support formation. The clearance may be almost exactly 0.3 mm. This clearance which may apply to the canister body itself or to the canister once a label has been applied, is enough to allow smooth motion of the canister in the inhaler while at the same time preventing substantial rocking of the canister which could result in inaccurate counting by a dose counter of the inhaler, especially when lower face of the canister is arranged to engage an actuator member of the dose counter for counting purposes.

According to a further aspect of the invention, a method of assembling a dose counter for an inhaler comprises the steps of providing a tape with dosing indicia thereon; providing tape positioning indicia on the tape; and stowing the tape while monitoring for the tape positioning indicia with a sensor. The method advantageously permits efficient and accurate stowing of the tape, e.g. by winding.

The dosing indicia may be provided as numbers, the tape positioning indicia may be provided as one or more lines across the tape. The stowing step comprises winding the tape onto a bobbin or shaft, and, optionally, stopping winding when the positioning indicia are in a predetermined position. The tape may be provided with pixelated indicia at a position spaced along the tape from the positioning indicia. The tape may also be provided with a priming dot.

According to a further aspect of the invention, a tape system for a dose counter for an inhaler has a main elongate tape structure, and dosing indicia and tape positioning indicia located on the tape structure. The tape positioning indicia may comprise at least one line extending across the tape structure. The tape system may comprise pixelated indicia located on the tape structure and spaced from the positioning indicia. The tape system may comprise a priming dot located on the tape structure. The positioning indicia may be located between the timing dot and the pixelated indicia. The main elongate tape structure may have at least one end thereof wound on a bobbin or shaft.

A further aspect of the invention provides a method of designing an incremental dose counter for an inhaler comprising the steps of calculating nominal canister fire and

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dose counter positions for a dose counter actuator of the inhaler; calculating a failure/success rate for dose counters built to tolerance levels for counting each fire of inhalers in which the dose counter actuators may be applied; and selecting a tolerance level to result in said failure/success rate to be at or below/above a predetermined value. This is highly advantageous in that it allows an efficient and accurate prediction of the reliability of a series of inhaler counters made in accordance with the design.

The method of designing may include selecting the failure/success rate as a failure rate of no more than one in 50 million. The method of designing may include setting an average count position for dose counters built to the tolerances to be at or after an average fire position thereof during canister firing motion. The method of designing may include setting the average count position to be about 0.4 to 0.6 mm after the average fire position, such as about 0.48 mm after. The method of designing may include setting tolerances for the standard deviation of the fire position in dose counters built to the tolerances to be about 0.12 to 0.16 mm, such as about 0.141 mm. The method of designing may include setting tolerances for the standard deviation of the count positions in dose counters built to the tolerances to be about 0.07 to 0.09 mm, such as about 0.08 mm. A further aspect of the invention provides a computer implemented method of designing an incremental dose counter for an inhaler which includes the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing in a production run a series of incremental dose counters for inhalers which comprises manufacturing the series of dose counters in accordance with the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing a series of incremental dose counters for inhalers, which comprises manufacturing the dose counters with nominal canister fire and dose count positions of a dose counter actuator relative to a dose counter chassis (or inhaler main body), and which includes building the dose counters with the average dose count position in the series being, in canister fire process, at or after the average canister fire position in the series.

According to a further aspect of the invention, the method provides fitting each dose counter in the series of incremental dose counters to a corresponding main body of an inhaler.

These aspects advantageously provide for the production run of a series of inhalers and dose counters which count reliably in operation.

According to a further aspect of the invention, an incremental dose counter for a metered dose inhaler has a body arranged to retain a canister for movement of the canister relative thereto, the incremental dose counter having a main body, an actuator arranged to be driven and to drive an incremental output member in a count direction in response to canister motion, the actuator being configured to restrict motion of the output member in a direction opposite to the count direction. This advantageously enables an inhaler dose counter to keep a reliable count of remaining doses even if dropped or otherwise jolted.

The output member may comprise a ratchet wheel. The actuator may comprise a pawl and in which the ratchet wheel and pawl are arranged to permit only one-way ratcheting motion of the wheel relative to the pawl. The dose counter may include an anti-back drive member fixed to the main body. In a rest position of the dose counter, the ratchet wheel is capable of adopting a configuration in which a back surface of one tooth thereof engages the anti-back drive member and the pawl is spaced from an adjacent back

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surface of another tooth of the ratchet wheel without positive drive/blocking engagement between the pawl and wheel.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be carried out in various ways and preferred embodiment of a dose counter, inhaler and methods of assembly, design and manufacture will now be described with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of a main body of an embodiment of an inhaler related to the invention together with a mouthpiece cap therefor;

FIG. 2 is a top plan view of the components as shown in FIG. 1;

FIG. 3A is a section on the plane 3A-3A in FIG. 2;

FIG. 3B is a view corresponding to FIG. 3A but with a dose counter fitted to the main body of the inhaler;

FIG. 4A is an exploded view of the inhaler main body, mouthpiece cap, dose counter and a dose counter window;

FIG. 4B is a view in the direction 4B in FIG. 4C of a spring retainer of the dose counter;

FIG. 4C is a top view of the spring retainer of FIG. 4B;

FIG. 5 is a bottom view of the assembled inhaler main body, mouthpiece cap, dose counter and dose counter window;

FIGS. 6A, 6B, 6C, 6D, 6E, 6F, 6G and 6H are various views of dose counter components of the inhaler;

FIGS. 7A and 7B are sectional views showing canister clearance inside the main body of the inhaler;

FIG. 7C is a further sectional view similar to that of FIG. 7B but with the canister removed;

FIG. 7D is a top plan view of the inhaler main body;

FIGS. 8A, 8B, 8C and 8D show the inhaler main body and dose counter components during assembly thereof;

FIG. 9 shows a sectional side view of a datum line for an actuator pawl of the dose counter;

FIGS. 10A, 10B, 10C, 10D, 10E and 10F show various side views of positions and configurations of the actuator pawl, a ratchet wheel, and a count pawl;

FIG. 11 shows distributions for tolerances of start, reset, fire, count and end positions for the actuator of the dose counter;

FIG. 12 is an enlarged version of part of FIG. 4A;

FIG. 13 shows an end portion of a tape of the dose counter;

FIG. 14 shows a computer system for designing the dose counter;

FIG. 15 is an isometric view of a stock bobbin modified in accordance with the present invention for use in the dose counter of the inhaler of FIGS. 1 to 14;

FIG. 16 shows an end view of the stock bobbin of FIG. 15;

FIG. 17 is a section through a longitudinal axis of the stock bobbin of FIGS. 15 and 16;

FIGS. 18A, 18B and 18C are views of the stock bobbin of FIGS. 15 to 17 mounted in the dose counter chassis of FIGS. 1 to 14, with the control elements of the forks of the second shaft (or split pin) having a profile slightly different to that in FIG. 6F, with the forks in a compressed configuration;

FIGS. 19A, 19B and 19C are views equivalent to FIGS. 18A to 18C but with the forks in a more expanded configuration due to a different rotational position of the stock bobbin;

FIG. 20 is an isometric view of the chassis assembled and including the stock bobbin of FIGS. 15 to 17 but excluding the tape for reasons of clarity;

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FIG. 21 is a view of a preferred embodiment of a dry powder inhaler in accordance with the present invention;

FIG. 22 is an exploded view of the inhaler of FIG. 21;

FIG. 23 is a view of a dose counter of the inhaler of FIG.

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FIG. 24 is an exploded view of the dose counter shown in FIG. 23;

FIG. 25 is an exploded view of parts of the inhaler of FIG. 21; and

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DETAILED DESCRIPTION OF THE  
INVENTION

15 FIG. 1 shows a main body 10 of a manually operated metered dose inhaler 12 in accordance with an embodiment related to the present invention and having a mouthpiece cap 14 securable over a mouthpiece 16 of the main body.

The main body has a canister chamber 18 into which a canister 20 (FIG. 7A) is slideable. The canister 20 has a generally cylindrical main side wall 24, joined by a tapered section 26 to a head portion 28 having a substantially flat lower face 30 which has an outer annular drive surface 32 arranged to engage upon and drive an actuation pin 34 of a dose counter 36 as will be described. Extending centrally and axially from the lower face 30 is a valve stem 38 which is arranged to sealingly engage in a valve stem block 40 of the main body 10 of the inhaler 12. The valve stem block 40 has a passageway 42 leading to a nozzle 44 for directing the contents of the canister 20, namely active drug and propellant, towards an air outlet 46 of the inhaler main body 12. It will be appreciated that due to gaps 48 between the canister 20 and an inner wall 50 of the main body 10 of the inhaler 12 an open top 52 of the main body 10 forms an air inlet into the inhaler 12 communicating via air passageway 54 with the air outlet 46, such that canister contents exiting nozzle 44 mix with air being sucked by the user through the air passageway 54 in order to pass together through the air outlet and into the mouth of the user (not shown).

The dose counter 36 will now be described. The dose counter 36 includes an actuation pin 34 biased upwardly from underneath by a return spring 56 once installed in the main body 10. As best shown in FIGS. 4A, 6H and 8A, the pin 34 has side surfaces 58, 60 arranged to slide between corresponding guide surfaces 62, 64 located in a dose counter chamber 66 of the main body 10, as well as an end stop surface 68 arranged to engage a corresponding end stop 70 formed in the dose counter chamber 66 to limit upward movement of the pin 34. The pin 34 has a top part 72 which is circularly cylindrical and extends through an aperture 74 formed through a separator wall 76 which separates the canister chamber 18 from the dose counter chamber 66. The top part 72 of the pin 34 has a flat top surface 78 which is arranged to engage the outer annular drive surface 32 of the canister 20.

The actuation pin 34 is integrally formed with a drive or actuator pawl 80. The actuator pawl 80 has a generally inverted U-shape configuration, having two mutually spaced and parallel arms 82, 84 extending from a base portion of the actuation pin 34, each holding at respective distal ends 88 thereof opposite ends of a pawl tooth member 90 which extends in a direction substantially perpendicular to the arms 82, 84, so as to provide what may be considered a "saddle" drive for pulling on each of the 11 drive teeth 92 of a ratchet wheel 94 of an incremental drive system 96 or ratchet mechanism 96 of the dose counter 36. As shown for example in FIG. 10B, the pawl tooth member 90 has a sharp lower

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longitudinal side edge 98 arranged to engage the drive teeth 92, the edge-to-surface contact provided by this engagement providing very accurate positioning of the actuator pawl 80 and resultant rotational positioning of the ratchet wheel 94.

The dose counter 36 also has a chassis preassembly 100 which, as shown in FIGS. 4A and 6A, includes a chassis 102 having a first shaft 104 receiving the ratchet wheel 94 which is secured to a tape reel shaft 106, and a second shaft (or split pin) 108 which is parallel to and spaced from the first shaft 104 and which slidably and rotationally receives a tape stock bobbin 110.

As shown in FIG. 6B, when the inhaler has not been used at all, the majority of a tape 112 is wound on the tape stock bobbin 110 and the tape 112 has a series of regularly spaced numbers 114 displayed therealong to indicate a number of remaining doses in the canister 20. As the inhaler is repeatedly used, the ratchet wheel 94 is rotated by the actuator pawl 80 due to operation of the actuation pin 34 by the canister 20 and the tape 112 is incrementally and gradually wound on to the tape reel shaft 106 from the second shaft 108. The tape 112 passes around a tape guide 116 of the chassis 102 enabling the numbers 114 to be displayed via a window 118 in a dose counter chamber cover 120 having a dose marker 132 formed or otherwise located thereon.

As shown in FIGS. 6A and 6D, the second shaft 108 is forked with two forks 124, 126. The forks 124, 126 are biased away from one another. The forks have located thereon at diametrically opposed positions on the second shaft 108 friction or control elements 128, 130, one on each fork. Each control element extends longitudinally along its respective fork 124, 126 and has a longitudinally extending friction surface 132, 134 which extends substantially parallel to a longitudinal axis of the second shaft and is adapted to engage inside a substantially cylindrical bore 136 inside the tape stock bobbin 110. This control arrangement provided between the bore 136 and the control elements 128, 130 provides good rotational control for the tape stock bobbin 110 such that it does not unwind undesirably such as when the inhaler is dropped. The tape force required to unwind the tape stock bobbin 110 and overcome this friction force is approximately 0.1 N.

As can be seen in FIG. 6D, as well as FIGS. 6G and 10A to 10F, the chassis 102 is provided with an anti-back drive tooth 138 or count pawl 138 which is resiliently and substantially fixedly mounted thereto. As will be described below and as can be seen in FIGS. 10A to 10F, when the actuation pin 34 is depressed fully so as to fire the metered valve (not shown) inside the canister 20, the actuator pawl 80 pulls down on one of the teeth 92 of the ratchet wheel 94 and rotates the wheel 94 anticlockwise as shown in FIG. 6D so as to jump one tooth 92 past the count pawl 138, thereby winding the tape 112 a distance incrementally relative to the dose marker 122 on the dose counter chamber 120 so as to indicate that one dose has been used.

With reference to FIG. 10B, the teeth of the ratchet wheel 94 have tips 143 which are radiused with a 0.1 mm radius between the flat surfaces 140, 142. The ratchet wheel 94 has a central axis 145 which is 0.11 mm above datum plane 220 (FIG. 9). A top/nose surface 147 of the anti-back drive tooth 138 is located 0.36 mm above the datum plane 220. The distance vertically (i.e. transverse to datum plane 220—FIG. 9) between the top nose surface 147 of the anti-back drive tooth is 0.25 mm from the central axis 145 of the wheel 94. Bump surface 144 has a lateral extent of 0.20 mm, with a vertical length of a flat 145' thereof being 1 mm, the width of the bump surface being 1.22 mm (in the direction of the axis 145), the top 149 of the bump surface 144 being 3.02

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mm vertically below the axis 145, and the flat 145' being spaced a distance sideways (i.e. parallel to the datum plane 220) 2.48 mm from the axis 145. The top surface 78 of the pin 34 (FIG. 6H) is 11.20 mm above the datum plane 220 (FIG. 9) when the actuator pawl 80 and pin 34 are in the start configuration. The length of the valve stem 22 is 11.39 mm and the drive surface 32 of the canister 20 is 11.39 mm above the datum plane 220 when the canister is at rest waiting to be actuated, such that there is a clearance of 0.19 mm between the canister 20 and the pin 34 in this configuration.

FIGS. 10A and 10B show the actuator pawl 80 and ratchet wheel 94 and count pawl 138 in a start position in which the flat top 78 of the pin 34 has not yet been engaged by the outer annular drive surface 32 of the canister 20 or at least has not been pushed down during a canister depression.

In this "start" position, the count pawl 138 engages on a non-return back surface 140 of one of the teeth 92 of the ratchet wheel 94. The lower side edge 98 of the actuator pawl is a distance "D" (FIG. 9) 1.33 mm above datum plane 220 which passes through bottom surface or shoulder 41 of valve stem block 40, the datum plane 220 being perpendicular to a main axis "X" of the main body 10 of the inhaler 12 which is coaxial with the centre of the valve stem block bore 43 and parallel to a direction of sliding of the canister 20 in the main body 10 of the inhaler 12 when the canister is fired.

As shown in FIG. 10B, an advantageous feature of the construction is that the pawl tooth/actuator 90 acts as a supplementary anti-back drive member when the inhaler 12 is not being used for inhalation. In particular, if the inhaler 12 is accidentally dropped, resulting in a jolt to the dose counter 36 then, if the wheel 94 would try to rotate clockwise (backwards) as shown in FIG. 10B, the back surface 140 of a tooth will engage and be blocked by the tooth member 90 of the pawl 80. Therefore, even if the anti-back drive tooth 138 is temporarily bent or overcome by such a jolt, undesirable backwards rotation of the wheel 94 is prevented and, upon the next canister firing sequence, the pawl 90 will force the wheel 94 to catch up to its correct position so that the dose counter 36 continues to provide correct dosage indication.

FIG. 10C shows a configuration in which the actuator pawl 80 has been depressed with the pin 34 by the canister 20 to a position in which the side edge 98 of the pawl tooth member 90 is just engaged with one of the teeth 92 and will therefore upon any further depression of the pin 34 begin to rotate the wheel 94. This is referred to as a "Reset" position or configuration. In this configuration, the lower side edge 98 of the actuator 80 is 0.64 mm above the datum plane 220.

FIG. 10D shows a configuration in which the actuator pawl 80 has been moved to a position lower than that shown in FIG. 10C and in which the metered dose valve (not shown) inside the canister has at this very position fired in order to eject active drug and propellant through the nozzle 44. It will be noted that in this configuration the count pawl 138 is very slightly spaced from the back surface 140 of the same tooth 92 that it was engaging in the configuration of FIG. 10D. The configuration shown in FIG. 10D is known as a "Fire" configuration. In this configuration the lower side edge 98 of the actuator 80 is 0.47 mm below the datum plane 220.

FIG. 10E shows a further step in the sequence, called a "Count" position in which the actuator pawl 80 has rotated the ratchet wheel 94 by the distance circumferentially angularly between two of the teeth 92, such that the count pawl 138 has just finished riding along a forward surface 142 of one of the teeth 92 and has resiliently jumped over the tooth



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into engagement with the back surface **140** of the next tooth. Accordingly, in this "Count" configuration, a sufficiently long stroke movement of the pin **34** has occurred that the tape **112** of the dose counter **36** will just have counted down one dose. In this configuration, the lower side edge **98** of the actuator is 0.95 mm below the datum plane **220**. Accordingly, in this position, the actuator **80** generally, including edge **98**, is 0.48 mm lower than in the fire configuration. It has been found that, although the count configuration happens further on than the fire configuration, counting is highly reliable, with less than 50 failed counts per million. This is at least partially due to momentum effects and to the canister releasing some back pressure on the user in some embodiments as its internal metering valve fires.

In the configuration of FIG. **10F**, the pawl **80** has been further depressed with the pin **34** by the canister **20** to a position in which it is just disengaging from one of the teeth **92** and the actuator pawl **80** is assisted in this disengagement by engagement of one of the arms **84** with a bump surface **144** on the chassis **102** (see FIG. **6G**) and it will be seen at this point of disengagement, which is called an "End" configuration, the count pawl **138** is positioned exactly halfway or substantially halfway between two of the drive teeth **92**. This advantageously means therefore that there is a minimum chance of any double counting or non-counting, which would be undesirable. In the end configuration, the side edge **98** of the actuator is 1.65 mm below the datum plane **220**. It will be appreciated that any further depression of the actuator pawl **80** and pin **34** past the "End" configuration shown in FIG. **10F** will have no effect on the position of the tape **112** displayed by the dose counter **36** since the actuator pawl **80** is disengaged from the ratchet wheel **94** when it is below the position shown in FIG. **10F**.

As shown in FIGS. **7C** and **7D**, the inner wall **50** of the main body **10** is provided with a two-step support rail **144** which extends longitudinally along inside the main body and is located directly adjacent the aperture **74**. As shown in FIG. **7B** a diametrically opposed two-step support rail **146** is also provided and this diametrically opposed in the sense that a vertical plane (not shown) can pass substantially directly through the first rail **144**, the aperture **74**, a central aperture **148** of the valve stem block **40** (in which canister stem **25** is located) and the second two-step support rail **146**. As shown in FIG. **7A** and schematically in FIG. **7B**, the rails **144**, **146** provide a maximum clearance between the canister **20** and the rails **144**, **146** in a radial direction of almost exactly 0.3 mm, about 0.25 to 0.35 mm being a typical range. This clearance in this plane means that the canister **20** can only rock backwards and forwards in this plane towards away from the actuation pin **34**. A relatively small distance and this therefore prevents the canister wobbling and changing the height of the actuation pin **34** as to undesirably alter the accuracy of the dose counter **36**. This is therefore highly advantageous.

The inner wall **50** of the main body **10** is provided with two further two-step rails **150** as well as two pairs **152**, **154** of rails extending different constant radial amounts inwardly from the inner wall **50**, so as to generally achieve a maximum clearance of almost exactly 0.3 mm around the canister **20** for all of the rails **144**, **146**, **150**, **152**, **154** spaced around the periphery of the inner wall **50**, in order to prevent undue rocking while still allowing canister motion freely inside the inhaler **12**. It will be clear from FIG. **7C** for example that the two-step rails have a first portion near an outlet end **156** of the canister chamber **18**, the first portion having a substantially constant radial or inwardly-extending width, a first step **160** leading to a second portion **162** of the rail, the

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second portion **102** having a lesser radial or inwardly extending extent than the first portion **156**, and finally a second step **164** at which the rail merges into the main inner wall **50** main surface.

A method of assembling the inhaler **12** will now be described.

With reference to FIG. **8A**, the main body **10** of the inhaler **12** is formed by two or more plastics mouldings which have been joined together to the configuration shown.

As shown in FIG. **8B**, the actuator pawl **80** and pin **34** are translated forward into position into a pin receiving area **166** in the dose counter chamber **66** and the pin **34** and actuator **80** may then be raised until the pin **34** emerges through the aperture **74**.

Next, the return spring **56** may be inserted below the pin **34** and a generally cylindrical annular lower end **168** of the spring **56** may be moved by a tweezer or tweezer-like assembly tool (not shown) into engagement with a shelf **170** of a spring retainer **172** in the dose counter chamber **66**. The spring retainer **172** is U-shaped and the shelf **170** is U-shaped and has a recess **174** formed below it. As shown in FIGS. **4B**, **4C** and **12** shelf **170** includes three chamfer surfaces **176**, **178**, **180** arranged to assist in moving the lower end of the spring **168** into position onto the shelf using the assembly tool (not shown). Once the lower end of the spring **168** is in place, the assembly tool (not shown) can easily be removed at least partly via the recess **174** below the lower end **168** of the spring **56**.

The tape **112** is attached at one end (not shown) to the tape stock bobbin **110** and is wound onto the bobbin by a motor **200** (FIG. **13**) having a hexagonal output shaft **202** which engages in a hexagonal socket **204** (FIG. **6B**) of the bobbin. During winding, the tape is monitored by a sensor **206**, which may be in the form of a camera or laser scanner, which feeds data to a computer controller **205** for the motor **200**. The controller **205** recognises three positioning markers **210** in the form of lines across the tape **112** and stops the motor **202** when the tape **112** is nearly fully wound onto the bobbin **110**, such that the distal end **212** of the tape **112** can be secured, e.g. by adhesive, to the tape reel shaft **106**. The controller **205** also recognises a pixelated tape size marker **214** observed by the sensor **206** and logs in a stocking system data store **217** details of the tape **112** such as the number of numbers **114** on the tape, such as one hundred and twenty or two hundred numbers **114**. Next, the tape reel shaft is wound until an appropriate position of the lines **210** at which a priming dot **216** will, once the bobbin **110** and reel shaft **106** are slid onto the second shaft **108** and second shaft **104**, be in a position to be located in the window **118** when the inhaler **12** is fully assembled. In the embodiments, the bobbin **110** and reel shaft **106** may be slid onto the shafts **108**, **104** before the tape **112** is secured to the reel shaft **106** and the reel shaft may then be wound to position the priming dot **216**.

Next, the assembled dose counter components of the chassis preassembly **100** shown in FIG. **6B** may as shown in FIG. **8C** be inserted into the dose counter chamber **66**, with pins **182**, **184**, **186** formed on the main body **10** in the dose counter chamber **66** passing through apertures or slots **188**, **190**, **192** formed on the chassis **102**, such that the pins **182**, **184**, **186** extend through (or at least into) the apertures or slots **188**, **190**, **192**. With the chassis **102** being relatively firmly pushed towards the main body **10**, the pins **182**, **184**, **186** are then heat staked and the chassis **102** is therefore after this held very firmly in position in the main body and is unable to move, thereby assisting in providing great accuracy for the dose counter **36**. Next, as shown in FIG. **8D**, the

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dose counter chamber cover **120** may be fitted over the dose counter chamber **66** and may be secured in place such as by welding, with the priming dot **216** being displayed through the window.

The user can, when readying the inhaler **12** for first use, prime the inhaler by depressing the canister **20** three times which will bring the first number **114** on the tape into display through the window **118** in place of the priming dot **216**, the number **114** shown in FIG. **8D** being “200”, thereby indicating that 200 doses are remaining to be dispensed from the canister **20** and inhaler **12**.

As shown in FIG. **8D**, and in FIG. **5**, an open drain hole **194** is provided at the bottom of the dose counter chamber **66** by a substantially semi-circular cut-out or recess formation **196** in a lower surface **198** of the main body **10** of the inhaler. Accordingly, if the user (not shown) should decide to wash the main body **10** of the inhaler, for example after encountering an unhygienic situation or simply as a matter of choice, the drain hole **194** allows initial draining of water from inside the dose counter chamber **66** and also thereafter evaporation of water or any aqueous matter in the dose counter chamber **66** so that the window **118** does not mist up undesirably.

FIG. **14** shows a computer system **230** for designing the dose counter **36** and in particular for calculating distributions representative of average positions and standard deviations in a production series of inhalers of the start, reset, fire, count and end positions of the actuator lower side edge **98** relative to the datum plane **220** (FIG. **9**) and therefore of the actuator pawl **80** generally relative to the ratchet wheel **94**, chassis **102** and, when the inhaler **12** is fully assembled, the main body **10** of the inhaler **12**. The computer system **230** includes a data store **232**, a CPU **234**, an input device **236** (such as a keyboard or communication port) and an output device **238** (such as a communications port, display screen and/or printer). A user may enter data via the input device **236** which may be used by the CPU **234** in a mathematical calculation to predict count failure rates when the various dose counters are to be built in a series with dose counter positions set with given averages and standard deviations and taking into account any momentum/inertia effects and metering valve user-back-pressure reduction effect which will occur upon canister firing of a given type of canister. The computer system **230** is thus mathematically used to design the distributions. For the inhaler **12** described herein with the dose counter **36** and canister **20**, the distributions are designed as shown in FIG. **11**. The x axis shows distance of the lower side surface **98** of the actuator **80** above the datum plane **220** and the y axis is representative of the distribution. Thus, curve **240** shows that the start configuration has an average 1.33 mm above the datum plane **200** (standard deviation is 0.1 mm), curve **242** shows that the reset configuration has an average of 0.64 mm above the datum plane **220** (standard deviation is 0.082 mm), curve **244** shows the fire configuration has an average 0.47 mm below the datum plane **220** (standard deviation is 0.141 mm), curve **246** shows the count configuration has an average 0.95 mm below the datum plane **220** (standard deviation is 0.080 mm), and curve **248** shows the end configuration has an average of 1.65 mm below the datum plane **220** (standard deviation is 0.144 mm).

FIGS. **15** to **20** show a version of the inhaler modified in accordance with the present invention. In these drawings, the same reference numerals have been used to those in the earlier drawings to denote the equivalent components. The inhaler **12** is the same as that in FIGS. **1** to **14** apart from the following modifications.

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First, it can be seen that there is a modification in that the drive teeth **92** of the ratchet wheel **94** have a different profile to that in FIGS. **1** to **14**. There are also only nine ratchet teeth **94** in this embodiment instead of eleven.

Additionally, as shown in FIGS. **18C** and **19C**, the control elements **128**, **130** on the forks **124**, **126** of the second shaft **108** have a tapered profile which is different to the profile of the control elements **128**, **130** shown in FIG. **6F**. Either profile can be used in the embodiment of FIGS. **15** to **20** however.

Furthermore, as shown in FIG. **15**, the tape stock bobbin **110** has an inwardly facing generally cylindrical engagement surface **300** with a wavelike form extending partially therealong. The engagement surface **300** has a cross-section **301** perpendicular to the longitudinal length of the stock bobbin **110** which is constant therealong. This cross-section **301** can be seen in FIG. **16** and consists of a series of ten regularly spaced concavities **302** and ten convex wall portions **304**. The convex wall portions **304** are equi-spaced between the concavities **302**. Each concavity **302** has a radius of 0.2 mm. Each convex wall portion **304** also has a radius of 0.2 mm. Finally, the cross section **301** also includes flat wall portions **306** between all of the radiused wall portions of the concavities **302** and convex wall portions **304**. The geometry of the cross-section **301** is therefore defined by the radii of the concavities **302** and convex wall portions **304**, the flat wall portions **306** and the fact that there are ten concavities **302** and convex wall portions **304**.

The minor diameter of the engagement surface **300**, i.e. between the tips of opposite convex wall portions **304**, is 2.46 mm. The major diameter of the engagement surface **300**, i.e. between the outermost portions of the concavities **302**, is 2.70 mm. The undeformed tip to tip maximum diameter of the forks **124**, **126** of the split pin (the second shaft) **108**, i.e. in the region of the maximum radial extent of the control elements **128**, **130**, is 3.1 millimeters and it will therefore be appreciated that the forks **124**, **126** are resiliently compressed once the stock bobbin **110** has been assembled onto the split pin **108** in all rotational configurations of the stock bobbin **110** relative to the split pin **108**. The minimum gap between the forks **124**, **126** in the plane of the cross sections of FIGS. **18C** and **19C** is 1 mm when the split pin **108** is in the undeformed, pre-inserted state. When the split pin **108** is at maximum compression, as shown in FIGS. **18A** to **18C** when the control elements **128**, **130** are shown to be engaged on top of the convex wall portions **304**, the gap **308** between the tips **310**, **312** of the forks **124**, **126** is 0.36 mm. On the other hand, when the split pin **108** is at minimum compression (once inserted into the stock bobbin) as shown in FIGS. **19A** to **19C**, when the control elements **128**, **130** rest in the concavities **302**, the gap between the tips **310**, **312** of the forks **124**, **126** is 0.6 mm. The control elements **128**, **130** are outwardly radiused with a radius also of 0.2 mm such that they can just rest on the concavities **302** with full surface contact (at least at an axial location on the split pin where the tapered control elements are at their maximum radial extent), without rattling in, locking onto or failing to fit in the concavities **302**. The radii of the control elements **128**, **130** is therefore preferably substantially the same as the radii of the concavities **302**.

It will be appreciated that whereas FIGS. **18B** and **19B** are end views along the coaxial axis of the stock bobbin **110** and split pin **108**, FIGS. **18A** and **19A** are cross-sections. FIG. **19A** is a section on the plane A-A' in FIG. **19C** and FIG. **18A** is a section at the same plane, but of course with the stock bobbin **110** rotated relative to the split pin **108**.

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As the inhaler 12 is used and the ratchet wheel 94 rotates in order to count used doses, the stock bobbin rotates incrementally through rotational positions in which rotation is resisted, i.e. due to increasing compression of the split pin 108 at such rotational positions, and rotational positions in which rotation is promoted, i.e. due to decreasing compression of the split pin 108 at such rotational positions and this may involve a click forward of the stock bobbin 110 to the next position equivalent to that in FIGS. 19A to 19C in which the control elements 128, 130 of the split pin art located in the concavities 302. This functionality firstly allows the stock bobbin to unwind during use as required, but also prevents the tape 112 from loosening during transit if the inhaler 12 is dropped, such as onto a hard surface. This is highly advantageous, since the tape 11 is prevented from moving to a position in which it will give an incorrect reading regarding the number of doses in the canister.

During compression and expansion of the forks in the radial direction between the two configurations shown in FIGS. 18C and 19C, the forks 124, 126 rotate about a point 316 on the split pin where the forks 124, 126 come together. This rotational action means that there is a camming action between the forks 124, 126 and the engagement surface 300 without significant friction but, nevertheless, the resilient forces provided by the regulator formed by the engagement surface 300 and forks 124, 126 are able to regulate unwinding of the tape such that it does not easily occur during transit or if the inhaler 12 is dropped. It has been found during testing that a force of 0.3 to 0.4 N needs to be applied to the tape 112 to overcome the regulator at the stock bobbin 110. 0.32 N is achieved with the control elements 128 having the profile shown in FIG. 19C and 0.38 N is achieved with the profile of the control elements 128 altered to be as shown as described with reference to FIG. 6F. These forces are substantially higher than the 0.1 N force mentioned above and undesirable movement of the tape is substantially avoided even if the inhaler is dropped onto a hard surface. The modified arrangement of FIGS. 15 to 20 does not provide this force "constantly" such that there is overall not an undesirably high friction of the tape 112 as it passes over the other components of the dose counter because, due to the incremental nature of the resilient forces at the regulator, the tape 112 can incrementally relax as it slides over the stationary chassis components.

Instead of having ten concavities 302 and convex wall portions 304, other numbers may be used, such as 8 or 12. However, it is preferred to have an even number, especially since two control elements 128, 130 are provided, so that all of the control elements 128, 130 will expand and contract simultaneously. However, other arrangements are envisaged with 3 or more forks and the number of concavities/convex wall portions may be maintained as an integer divisible by the number of forks to maintain a system with simultaneous expansion/contraction. For example, the use of 9, 12 or 15 concavities/convex wall portions with 3 forks is envisaged.

Instead of having the engagement surface 300 on the inside of the stock bobbin 110, it could be placed on the outside of the stock bobbin 110 so as to be engaged by flexible external legs/pawls or similar.

It will be noted that the regulator provided by the engagement surface 300 and forks 124, 126 does not only allow rotation of the stock bobbin in one direction as is the case with the ratchet wheel 94. Rotation in both directions is possible, i.e. forwards and backwards. This means that during assembly, the stock bobbin 110 can be wound backwards during or after fitting the bobbin 100, shaft 106 and tape 112 onto the carriage 102, if desired.

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The stock bobbin 110 and the carriage 102 including the split pin 108 are both moulded of polypropylene material.

It will be seen from FIG. 16 that the cross-sectional shape 301 is not symmetrical within the hexagonal socket 204. This has enabled the hexagonal socket 204 to be maintained at a useful size while still allowing the desired size and geometry of the cross section 301 to fit without interfering with the hexagonal shape of the hexagonal socket 204 and also permits moulding to work during manufacture.

As shown in FIG. 17, the stock bobbin 110 has a series of four circumferential ribs 330 inside it and a spaced therealong. These hold the stock bobbin 110 on the correct side of the mould tool during moulding.

FIGS. 21 and 22 show a preferred embodiment in accordance with the invention of an inhaler 510 for dispensing a dry-powdered medicament in metered doses for patient inhalation. The inhaler 510 is as disclosed in FIGS. 1 to 16 or EP-A-1330280, the contents of which are hereby fully incorporated herein by reference, but with the stock bobbin 110 and second shaft 108 of the dose counter 516 modified so as to be as in FIGS. 15 to 20 hereof. Thus, the dry powder inhaler 510 generally includes a housing 518, and an assembly 512 received in the housing (see FIG. 21). The housing 518 includes a case 520 having an open end 522 and a mouthpiece 524 (FIG. 25) for patient inhalation, a cap 526 secured to and closing the open end 522 of the case 520, and a cover 528 pivotally mounted to the case 520 for covering the mouthpiece 524. As shown in FIG. 22, the inhaler 510 also includes an actuation spring 569, first yoke 566 with opening 572, bellows 540 with crown 574, a reservoir 514, second yoke 568 with hopper 542 and dose counter 516 mounted thereto, and case 520 has transparent window 5130 thereon for viewing dose counter tape indicia 5128. The dose metering system also includes two cams 570 mounted on the mouthpiece cover 528 and movable with the cover 528 between open and closed positions. The cams 570 each include an opening 580 for allowing outwardly extending hinges 582 of the case 520 to pass therethrough and be received in first recesses 584 of the cover 528. The cams 570 also include bosses 586 extending outwardly and received in second recesses 588 of the cover 528, such that the cover 528 pivots about the hinges 582 and the cams 570 move with the cover 528 about the hinges 582. As described in EP-A-1330280, cams 570 act upon cam followers 578 to move second yoke 568 up and down and thereby operate dose counter by engagement of pawl 5138 on the second yoke 568 with teeth 5136. Remaining components of the inhaler are provided as, and operate as described, in EP-A-1330280.

The dose counting system 516 therefore includes a ribbon or tape 5128 (FIGS. 23 & 24), having successive numbers or other suitable indicia printed thereon, in alignment with a transparent window 5130 provided in the housing 18 (see FIG. 22). The dose counting system 516 includes the rotatable stock bobbin 110 (as described above), an indexing spool 5134 rotatable in a single direction, and the ribbon 5128 rolled and received on the bobbin 110 and having a first end 5127 secured to the spool 5134, wherein the ribbon 5128 unrolls from the bobbin 110 so that the indicia are successively displayed as the spool 5134 is rotated or advanced. In FIGS. 23 and 24 the wavelike engagement surface 300 of the bobbin 110 is not shown for the purposes of clarity.

The spool 134 is arranged to rotate upon movement of the yokes 566, 568 to effect delivery of a dose of medicament from reservoir 514, such that the number on the ribbon 5128 is advanced to indicate that another dose has been dispensed by the inhaler 510. The ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase or



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decrease upon rotation of the spool **5134**. For example, the ribbon **5128** can be arranged such that the numbers, or other suitable indicia, decrease upon rotation of the spool **5134** to indicate the number of doses remaining in the inhaler **510**. Alternatively, the ribbon **5128** can be arranged such that the numbers, or other suitable indicia, increase upon rotation of the spool **5134** to indicate the number of doses dispensed by the inhaler **10**.

The indexing spool **5134** includes radially extending teeth **5136**, which are engaged by pawl **5138** extending from a cam follower **578** of the second yoke **568** upon movement of the yoke to rotate, or advance, the indexing spool **5134**. More particularly, the pawl **5138** is shaped and arranged such that it engages the teeth **5136** and advances the indexing spool **5134** only upon the mouthpiece cover **528** being closed and the yokes **566**, **568** moved back towards the cap **526** of the housing **518**.

The dose counting system **516** also includes a chassis **5140** that secures the dose counting system to the hopper **542** and includes shafts **108**, **5144** for receiving the bobbin **110** and the indexing spool **5134**. As described above with reference to FIGS. 1 to 20, the bobbin shaft **108** is forked and includes radially nubs **5146** for creating a resilient resistance to rotation of the bobbin **110** on the shaft **108** by engaging with the wavelike engagement surface **300** inside the bobbin **110**. A clutch spring **5148** is received on the end of the indexing spool **5134** and locked to the chassis **5140** to allow rotation of the spool **5134** in only a single direction.

Various modifications may be made to the embodiment shown without departing from the scope of the invention as defined by the accompanying claims as interpreted under patent law.

What is claimed is:

1. An inhaler for metered dose inhalation, the inhaler comprising:

a main body having a canister housing,  
a medicament canister, which is moveable relative to the canister housing and retained in a central outlet port of the canister housing arranged to mate with a canister fire stem of the medicament canister, and

a dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of the medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall, wherein the canister housing has a longitudinal axis X which passes through the center of the central outlet port, and

wherein the first inner wall canister support formation, the actuation member, and the central outlet port lie in a common plane coincident with the longitudinal axis X such that the first inner wall canister support formation protects against unwanted actuation of the dose counter by reducing rocking of the medicament canister relative to the main body of the inhaler.

2. The inhaler as claimed in claim 1 wherein the medicament canister is movable relative to the dose counter.

3. The inhaler as claimed in claim 1 further comprising an aperture formed in the inner wall through which the portion of the actuation member extends.

4. The inhaler as claimed in claim 1, wherein the first inner wall canister support formation comprises a support rail which extends longitudinally along an inside surface of the main body.

5. The inhaler as claimed in claim 4, wherein the support rail includes a step formed thereon.

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6. The inhaler as claimed in claim 4 further comprising a plurality of support rails each of which extends longitudinally along the inside surface of the main body.

7. The inhaler as claimed in claim 6, wherein two of the plurality of support rails are positioned at opposite ends of the inside surface of the main body to face each other.

8. The inhaler as claimed in claim 4, wherein the support rail includes two steps formed thereon, the steps being spaced apart longitudinally along an inside surface of the main body.

9. The inhaler as claimed in claim 4, wherein the support rail merges with the inner wall at a location adjacent the aperture.

10. The inhaler as claimed in claim 9, wherein a width dimension of the support rail is not constant, and the width dimension is greatest at the location where the support rail merges with the inner wall.

11. The inhaler as claimed in claim 1 further comprising a second inner wall canister support formation and wherein the second inner wall canister support formation, the first inner wall canister support formation, the actuation member and the central outlet port lie in a common plane coincident with longitudinal axis X.

12. An inhaler for metered dose inhalation, the inhaler comprising:

a main body having a canister housing,

a medicament canister, which is moveable relative to the canister housing and retained in a central outlet port of the canister housing arranged to mate with a canister fire stem of the medicament canister, and

a dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of the medicament canister,

wherein the canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall,

wherein the canister housing has a longitudinal axis X which passes through the center of the central outlet port, and

wherein the first inner wall canister support formation, the actuation member, and the central outlet port lie in a common plane coincident with the longitudinal axis X such that the first inner wall canister support formation protects against dose count errors by reducing rocking of the medicament canister towards or away from the actuation member.

13. An inhaler for metered dose inhalation, the inhaler comprising:

a main body having a canister housing,

a medicament canister retained in the canister housing and movable relative thereto, and a dose counter, the dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of the medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall,

wherein the canister housing has an aperture formed in the inner wall through which the portion of the actuation member extends, and

wherein the first inner wall canister support formation extends from the main surface of the inner wall to the aperture.

14. The inhaler as claimed in claim 13 wherein the medicament canister is movable relative to the dose counter.



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15. The inhaler as claimed in claim 13, wherein the first inner wall canister support formation comprises a support rail which extends longitudinally along an inside surface of the main body.

16. The inhaler as claimed in claim 15, wherein the support rail includes a step formed thereon.

17. The inhaler as claimed in claim 15 further comprising a plurality of support rails each of which extends longitudinally along the inside surface of the main body.

18. The inhaler as claimed in claim 17, wherein two of the plurality of support rails are positioned at opposite ends of the inside surface of the main body to face each other.

19. The inhaler as claimed in claim 15, wherein the support rail includes two steps formed thereon, the steps being spaced apart longitudinally along the inside surface of the main body.

20. The inhaler as claimed in claim 15, wherein a width dimension of the support rail is not constant, and the width dimension is greatest at the location where the support rail is closest to the aperture.

21. The inhaler as claimed in claim 13, wherein the first inner wall canister support formation, the aperture, and a central outlet port of the canister housing arranged to mate with a canister fire stem of the medicament canister, all lie in a common plane coincident with a longitudinal axis X which passes through the center of the central outlet port.

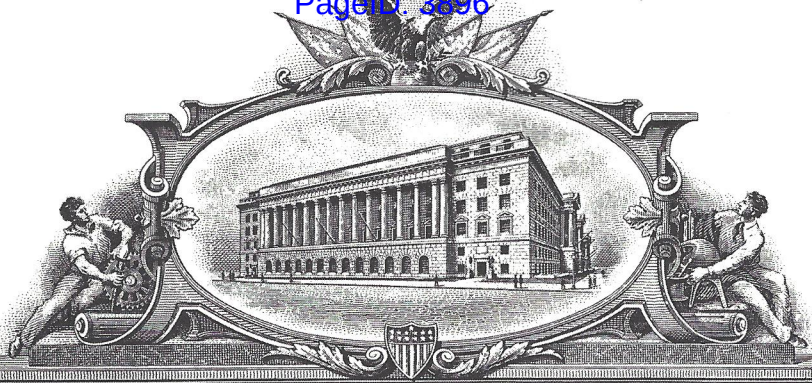
22. The inhaler as claimed in claim 21 further comprising a second inner wall canister support formation and wherein the second inner wall canister support formation, the first inner wall canister support formation, the aperture, and the central outlet port lie in a common plane coincident with longitudinal axis X.

\* \* \* \* \*

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## **EXHIBIT 3**

U 8079874



# THE UNITED STATES OF AMERICA

**TO ALL TO WHOM THESE PRESENTS SHALL COME:**

**UNITED STATES DEPARTMENT OF COMMERCE**

**United States Patent and Trademark Office**

February 26, 2021

**THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM  
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**U.S. PATENT: 10,086,156**

**ISSUE DATE: October 02, 2018**

**By Authority of the**

**Under Secretary of Commerce for Intellectual Property  
and Director of the United States Patent and Trademark Office**



  
**P. R. GRANT**  
**Certifying Officer**

(12) **United States Patent**  
**Walsh et al.**

(10) **Patent No.:** **US 10,086,156 B2**

(45) **Date of Patent:** **Oct. 2, 2018**

(54) **DOSE COUNTER FOR INHALER AND METHOD FOR COUNTING DOSES**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/699,567**

(22) Filed: **Apr. 29, 2015**

(65) **Prior Publication Data**

US 2015/0238714 A1 Aug. 27, 2015

**Related U.S. Application Data**

(60) Continuation of application No. 14/103,353, filed on Dec. 11, 2013, which is a division of application No. (Continued)

(51) **Int. Cl.**  
**G06M 1/06** (2006.01)  
**A61M 11/00** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC ..... **A61M 15/0078** (2014.02); **A61M 11/00** (2013.01); **A61M 15/009** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
CPC ..... **A61M 11/00**; **A61M 15/00**; **G06M 1/06**  
(Continued)

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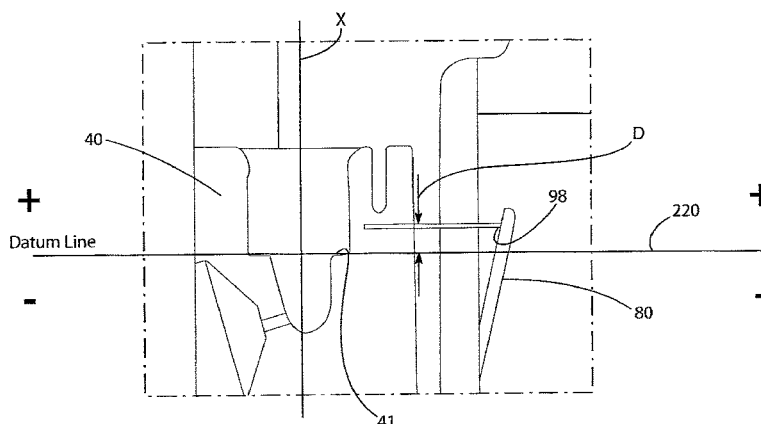
*Primary Examiner* — Daniel Hess

(74) *Attorney, Agent, or Firm* — Morgan, Lewis & Bockius, LLP

(57) **ABSTRACT**

A dose counter for a metered dose inhaler includes an incremental counting system for counting doses. The incremental counting system has a main body, an actuator arranged to be driven in response to canister motion and to drive an incremental output member in response to canister motion. The actuator and incremental output member are configured to have predetermined canister fire and count configurations in a canister fire sequence. The canister fire configuration is determined by a position of the actuator relative to a datum at which the canister fires medicament

(Continued)



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and the count configuration is determined by a position of the actuator relative to the datum at which the incremental count system makes an incremental count. The actuator is arranged to reach a position in the count configuration at or after a position in the canister fire configuration.

## 13 Claims, 17 Drawing Sheets

## Related U.S. Application Data

- 13/110,532, filed on May 18, 2011, now Pat. No. 8,978,966.
- (60) Provisional application No. 61/345,763, filed on May 18, 2010, provisional application No. 61/417,659, filed on Nov. 29, 2010.
- (51) **Int. Cl.**  
*A61M 15/00* (2006.01)  
*G06M 1/24* (2006.01)
- (52) **U.S. Cl.**  
CPC .... *A61M 15/0025* (2014.02); *A61M 15/0026* (2014.02); *A61M 15/0065* (2013.01); *A61M 15/0071* (2014.02); *G06M 1/246* (2013.01); *A61M 2202/064* (2013.01); *A61M 2205/6063* (2013.01); *A61M 2207/00* (2013.01); *A61M 2207/10* (2013.01); *Y10T 29/49* (2015.01); *Y10T 29/49764* (2015.01); *Y10T 29/49826* (2015.01)
- (58) **Field of Classification Search**  
USPC ..... 235/103; 128/200.23  
See application file for complete search history.

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File History for U.S. Appl. No. 15/289,553.

File History for U.S. Appl. No. 15/269,249.

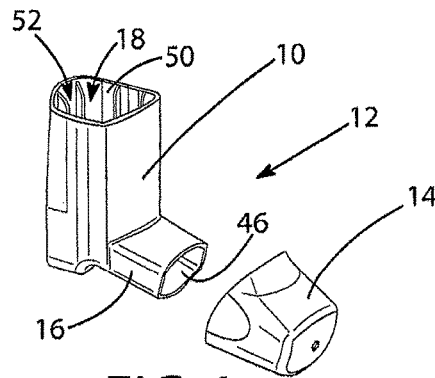


FIG. 1

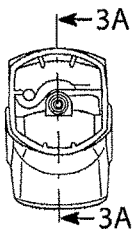


FIG. 2

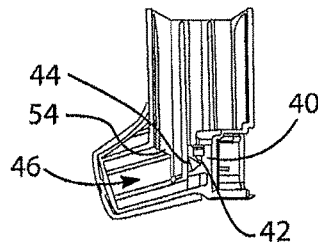


FIG. 3A

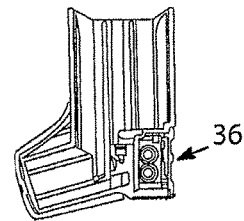


FIG. 3B

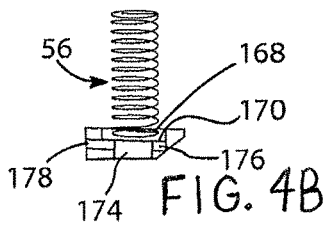


FIG. 4B

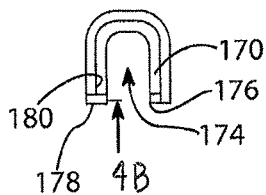


FIG. 4C

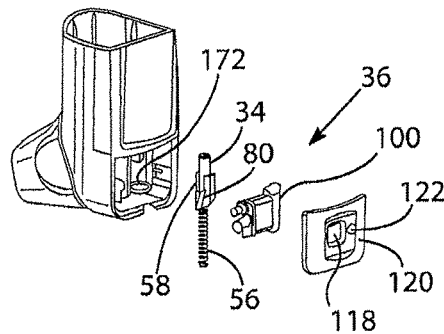


FIG. 4A

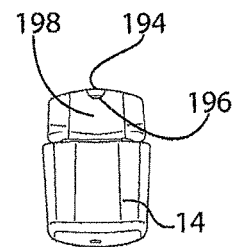


FIG. 5



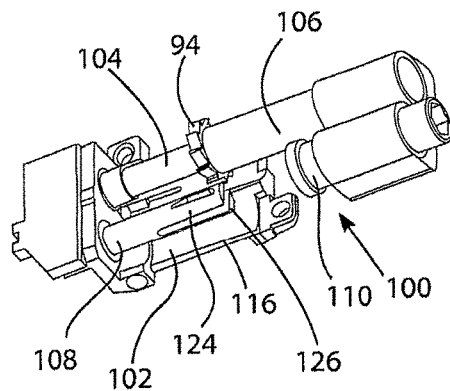


FIG. 6A

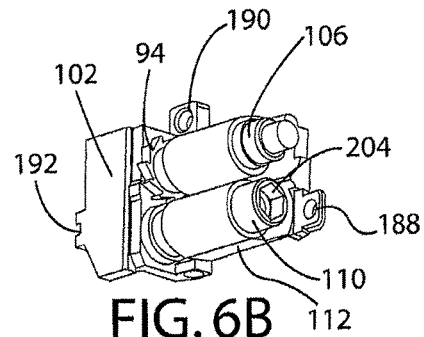


FIG. 6B

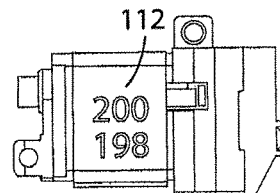


FIG. 6C

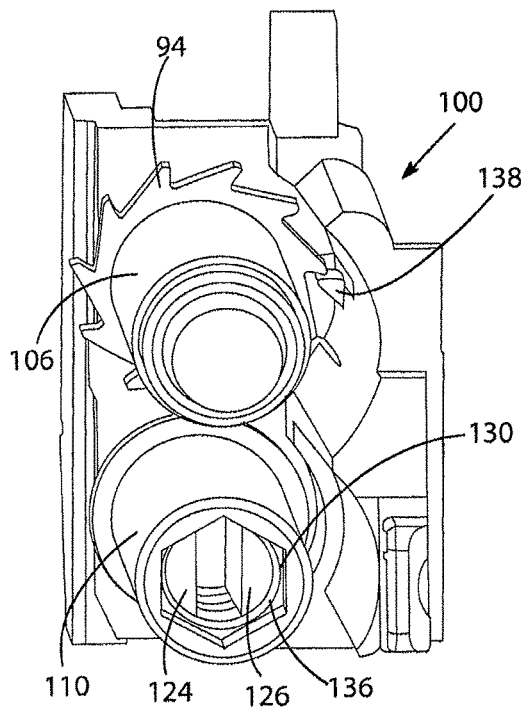


FIG. 6D

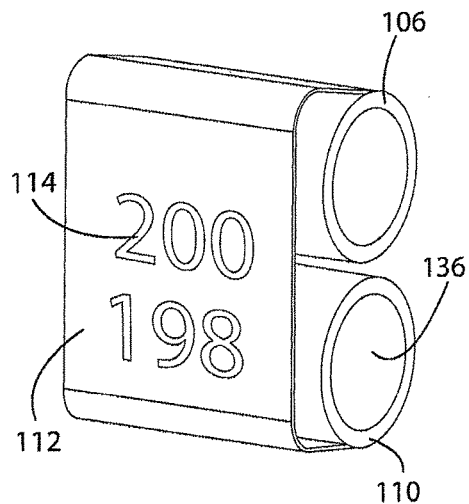


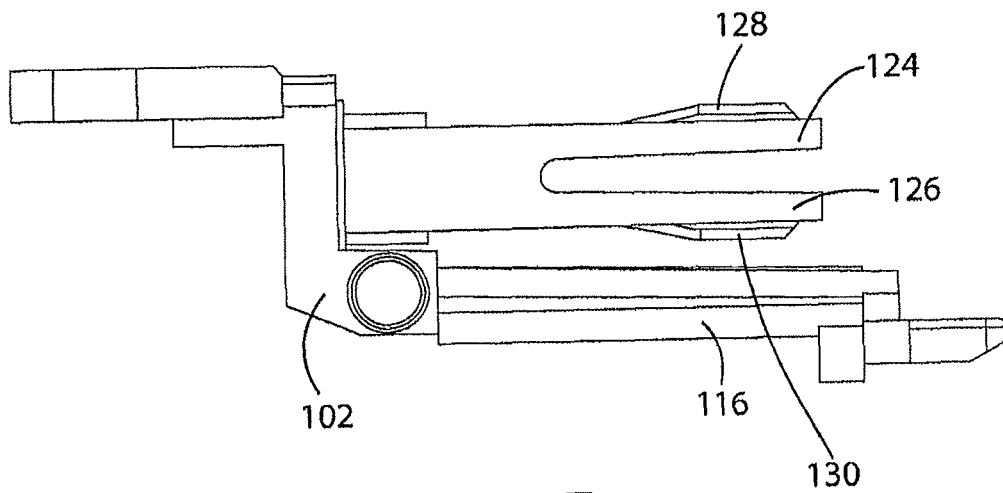
FIG. 6E

**U.S. Patent**

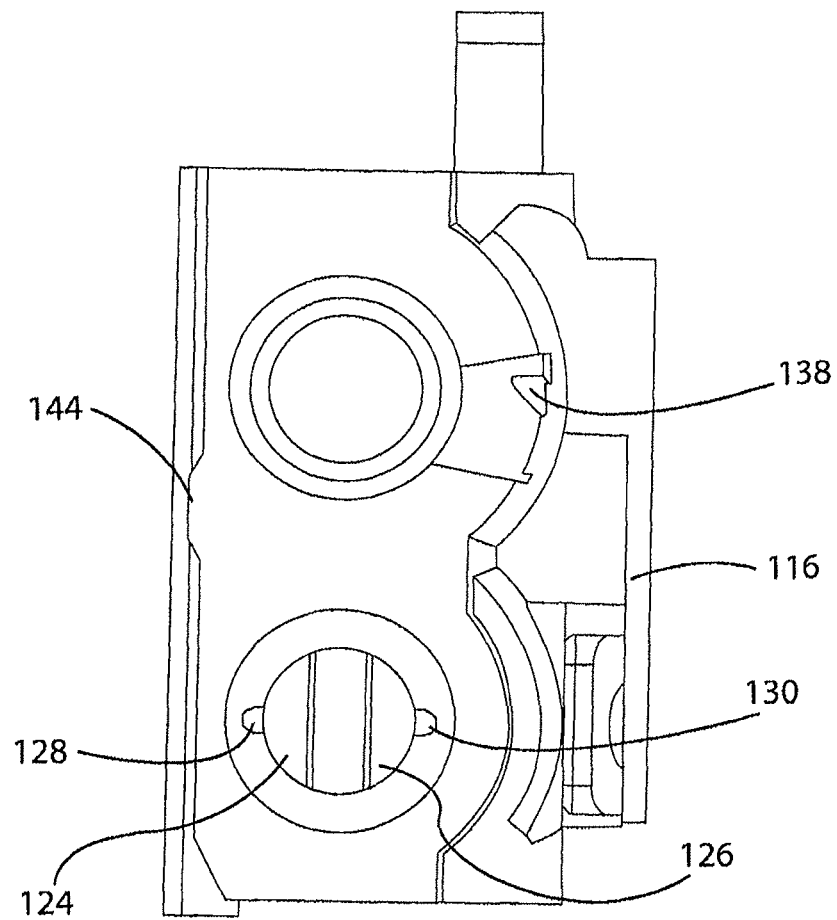
**Oct. 2, 2018**

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**FIG. 6F**



**FIG. 6G**

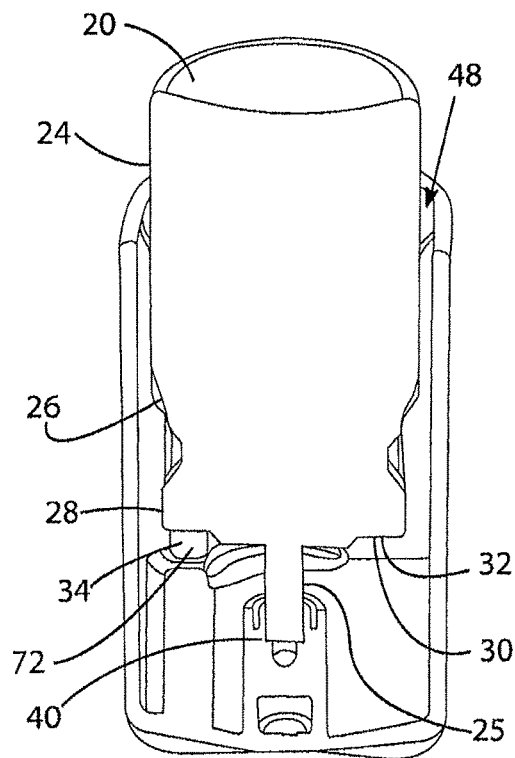


FIG. 7A

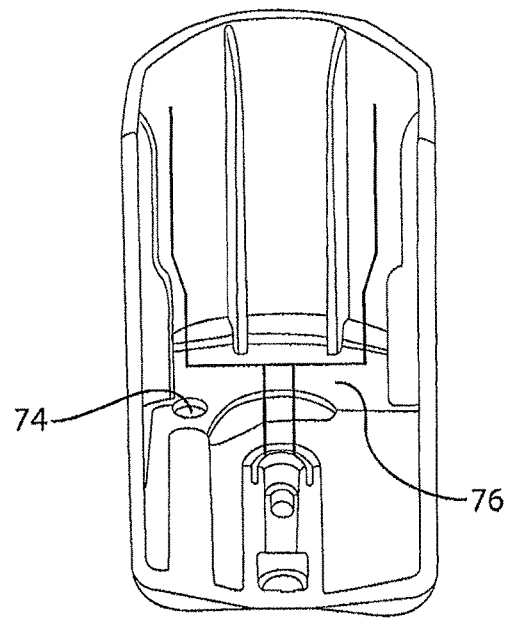


FIG. 7B

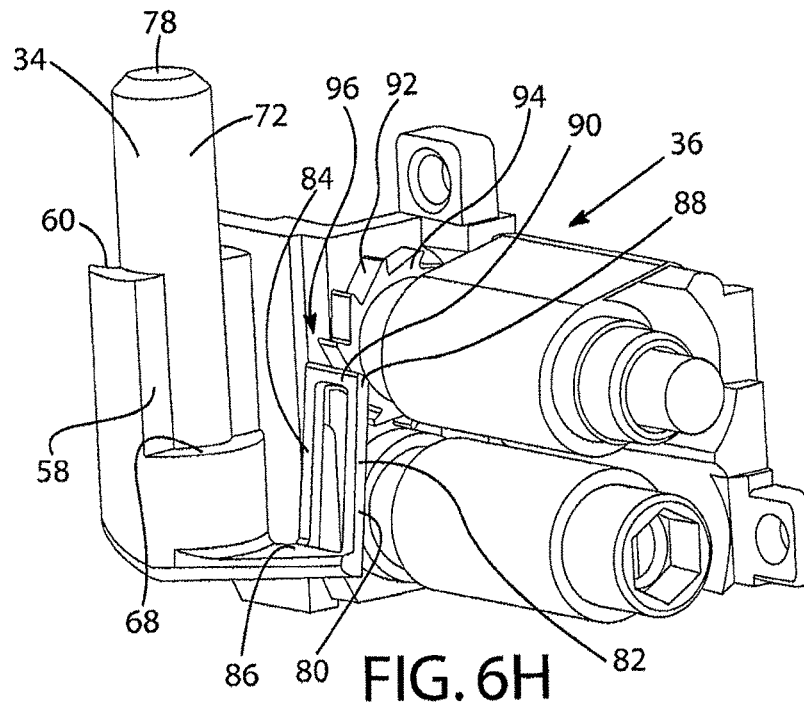
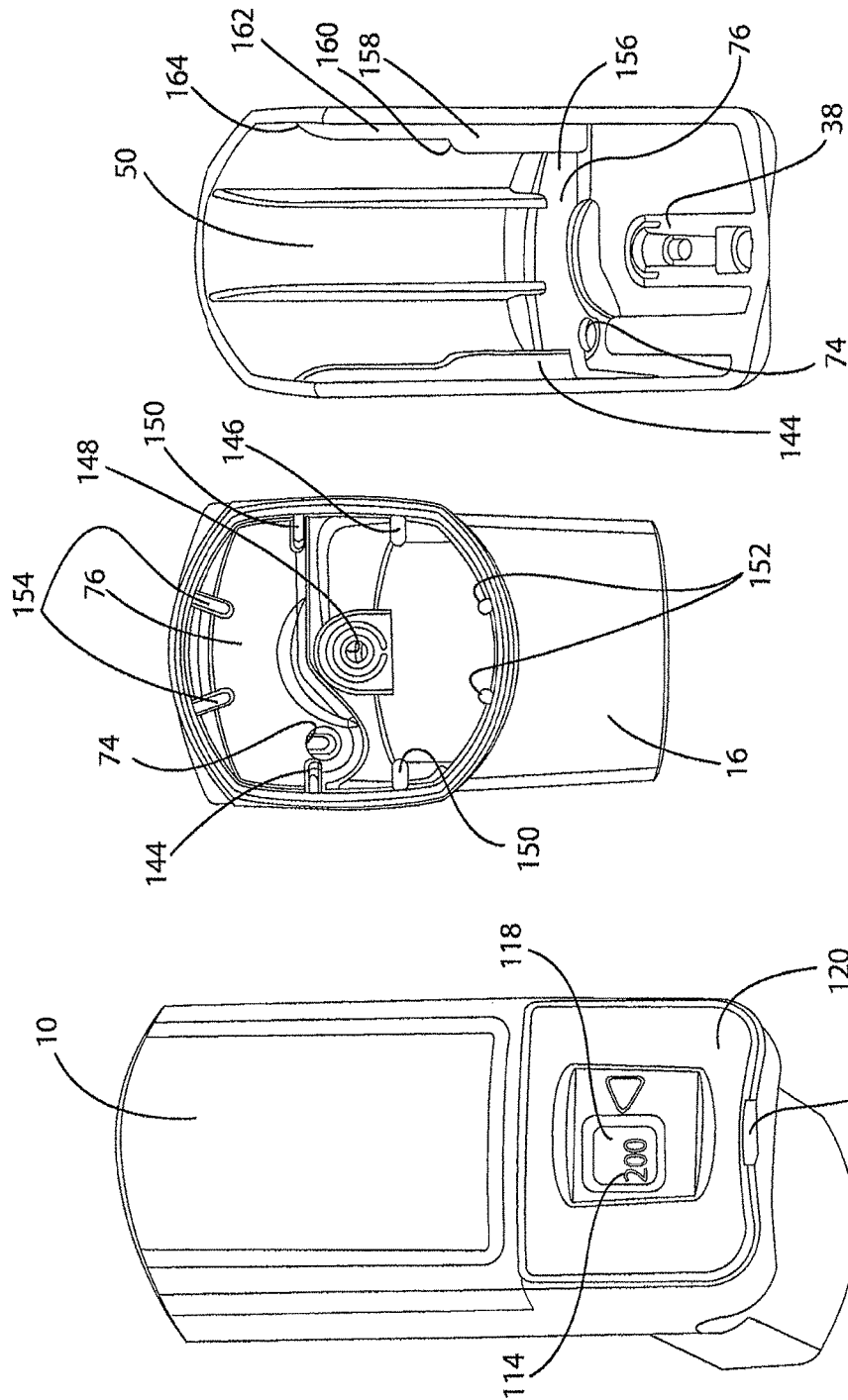


FIG. 6H



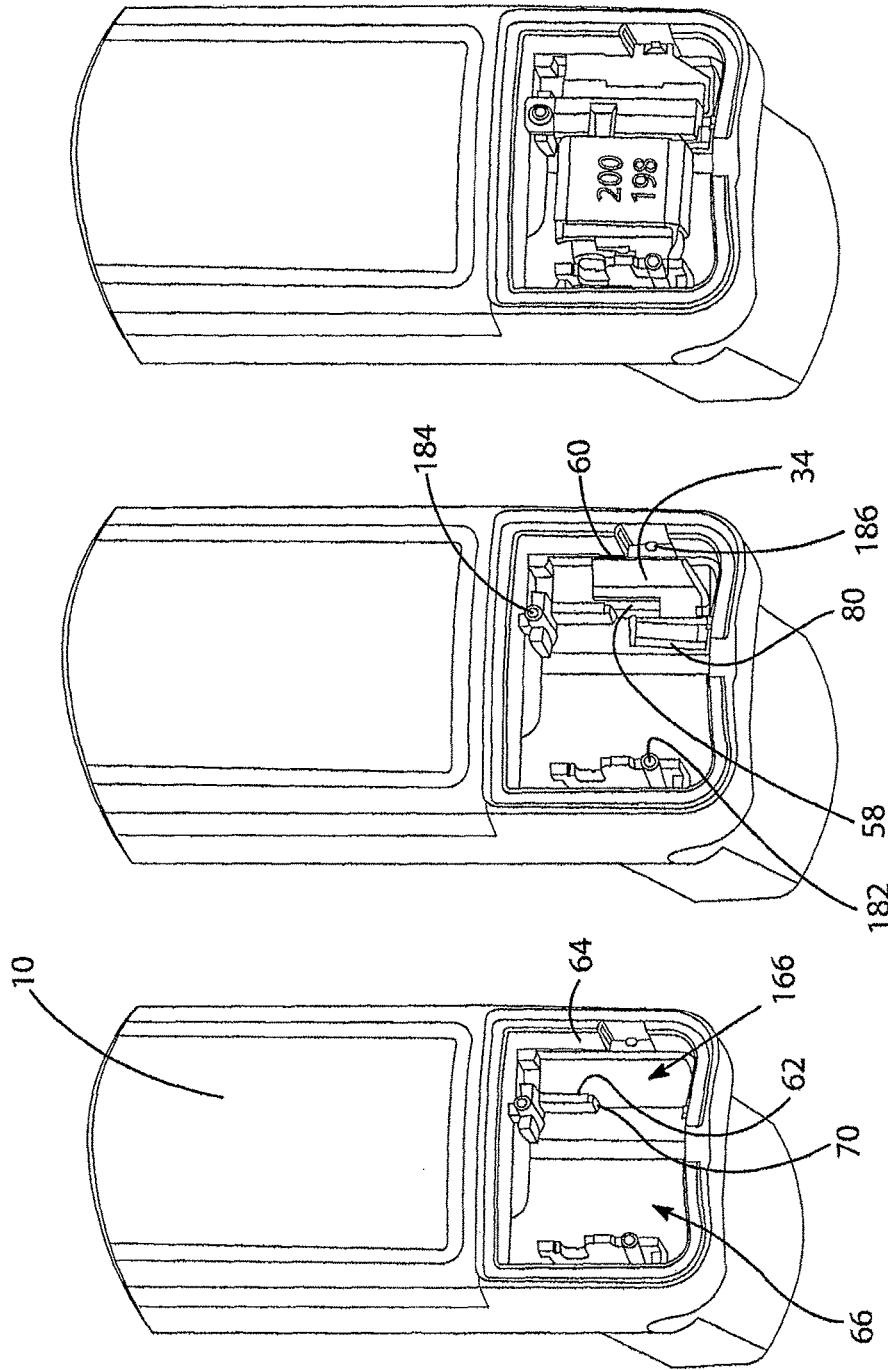
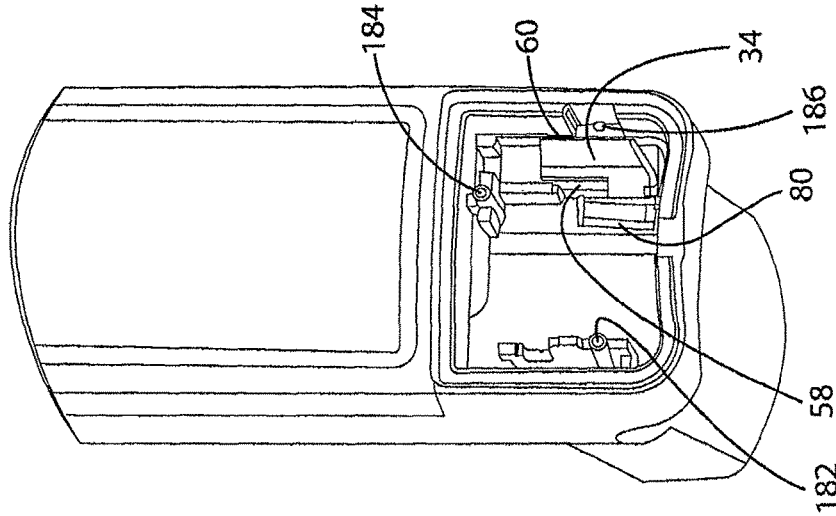


FIG. 8A



**FIG. 8B**

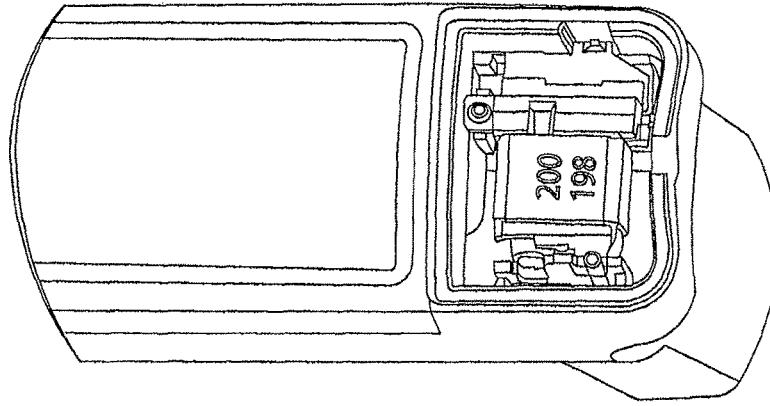


FIG. 8C

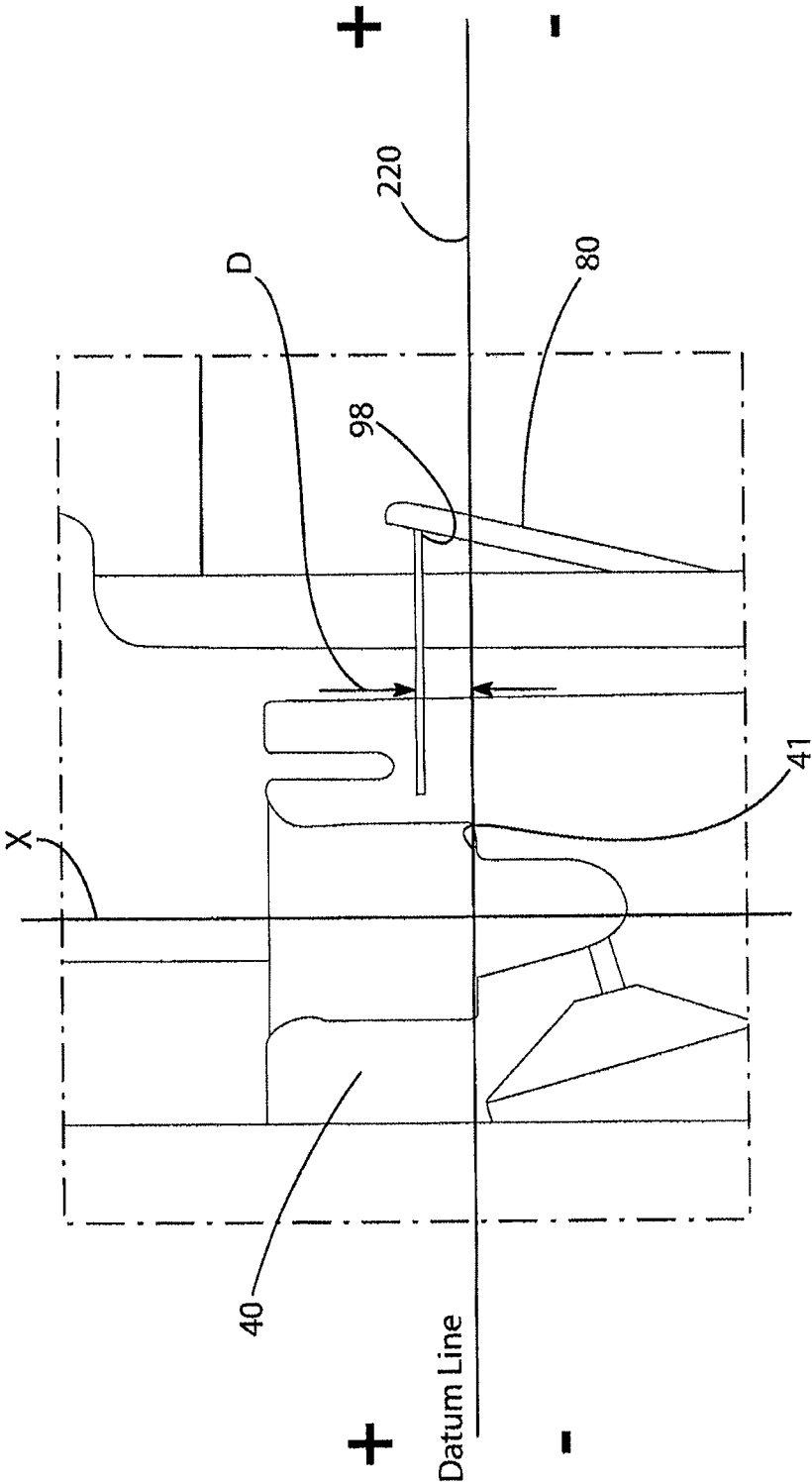


FIG. 9

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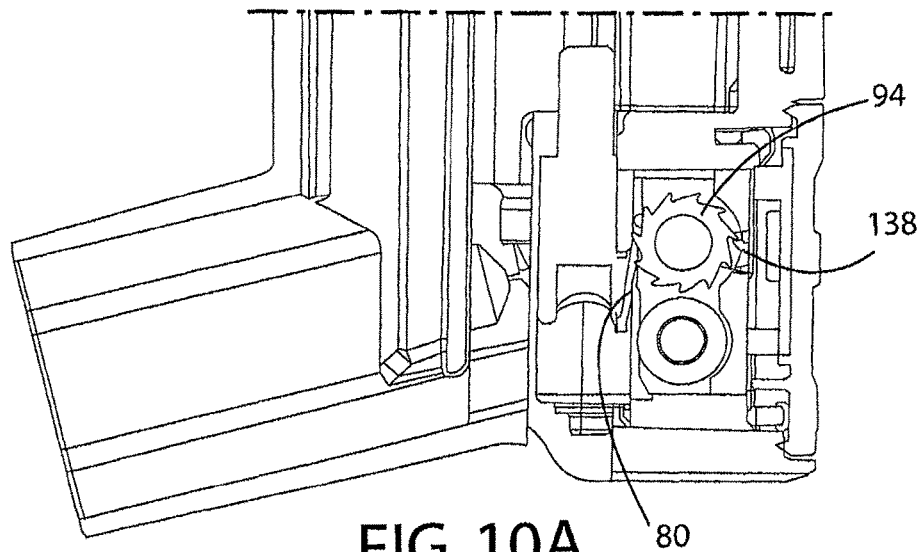


FIG. 10A

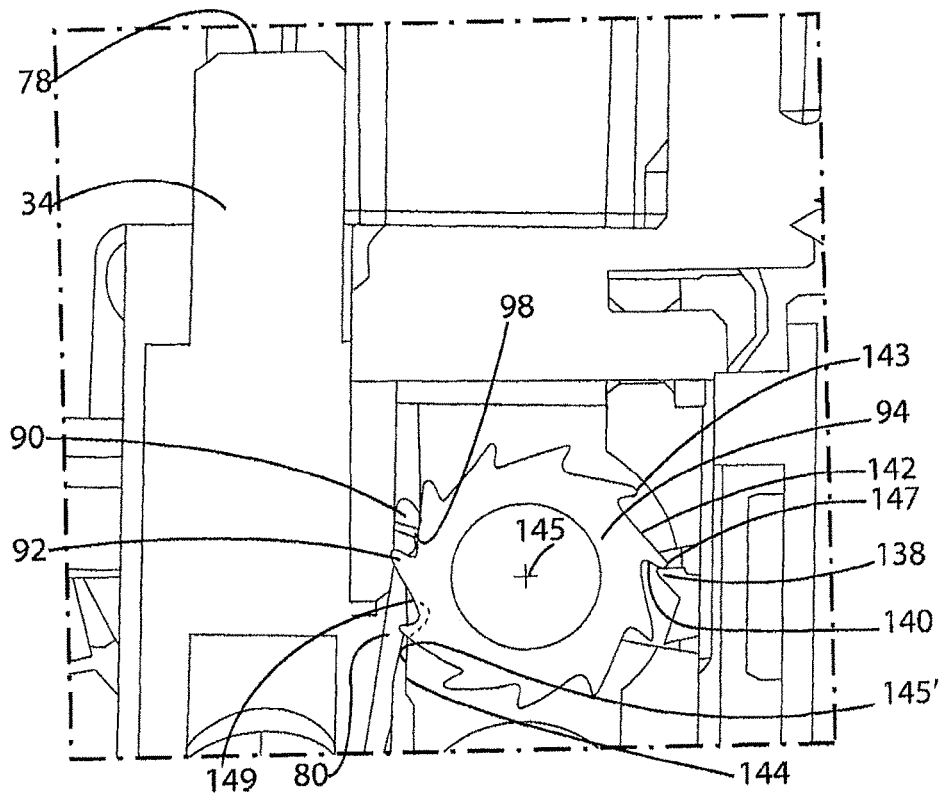


FIG. 10B



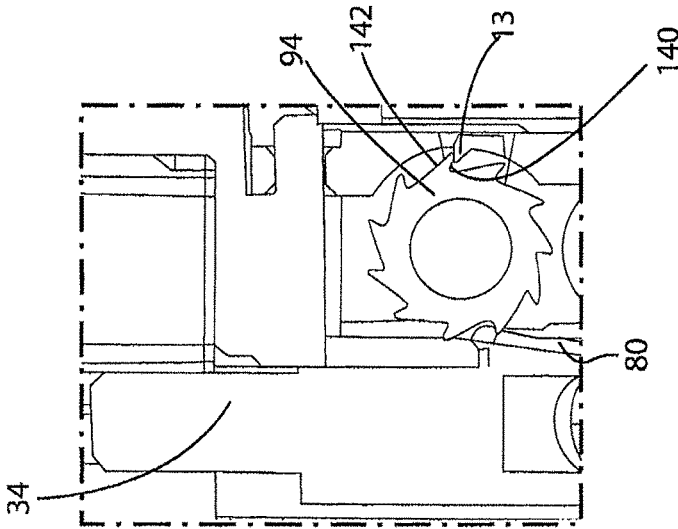


FIG. 10E

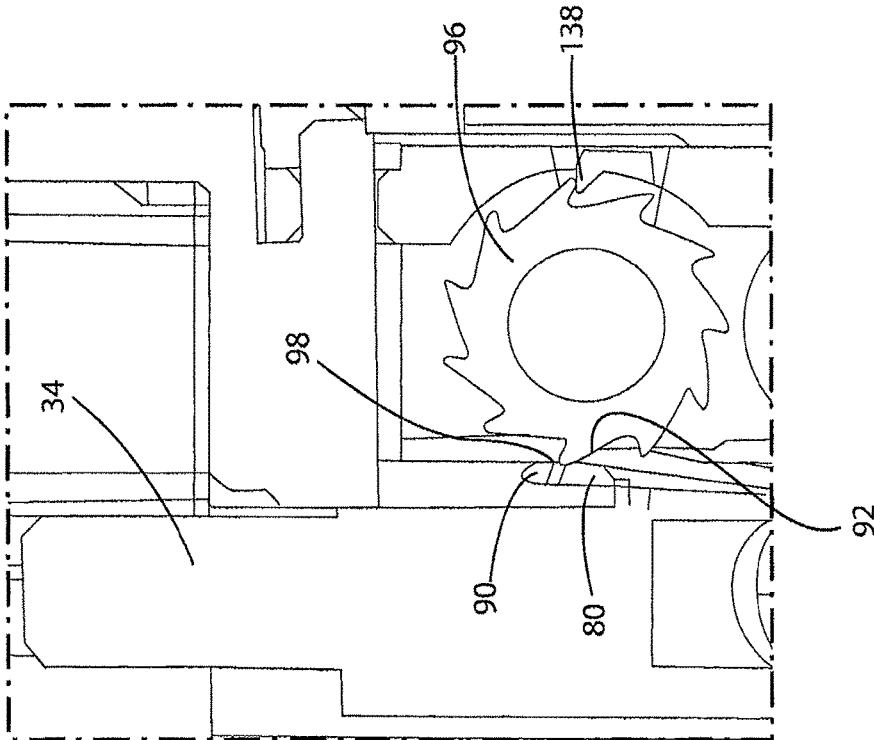


FIG. 10C

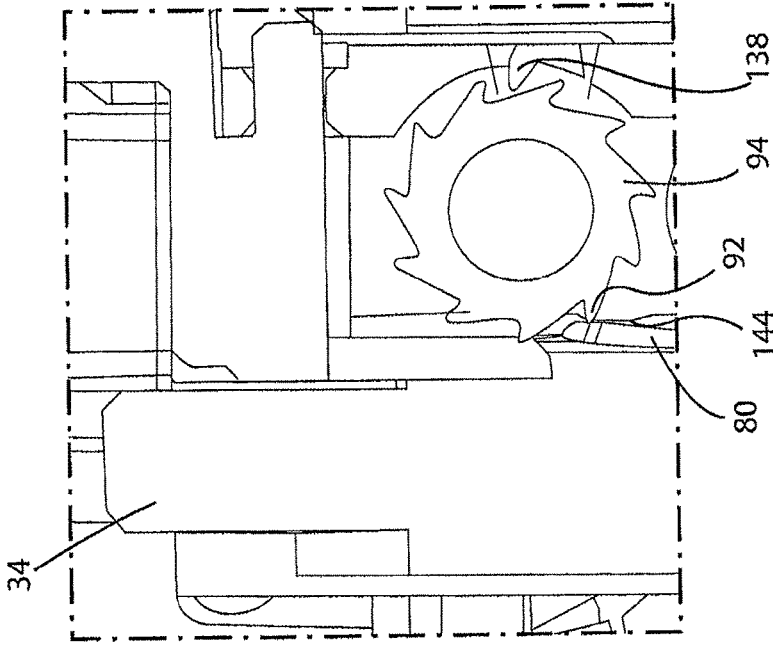


FIG. 10F

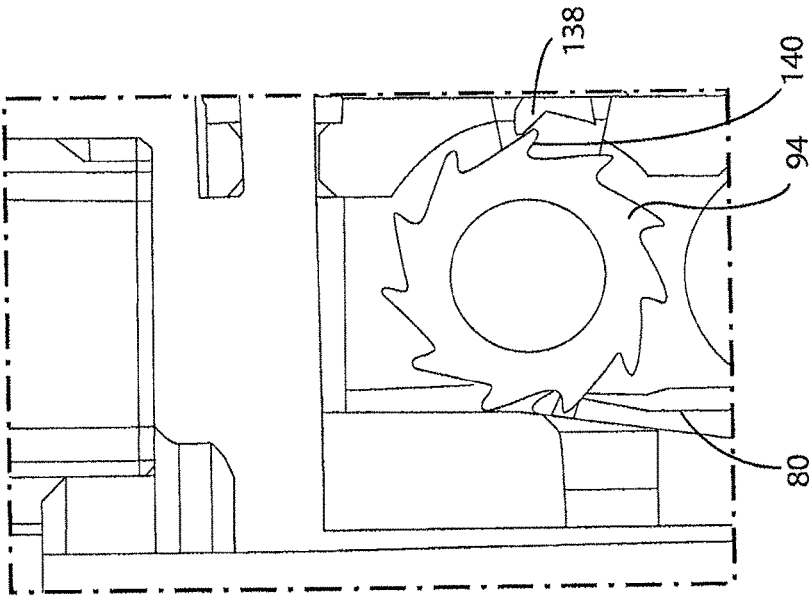


FIG. 10D

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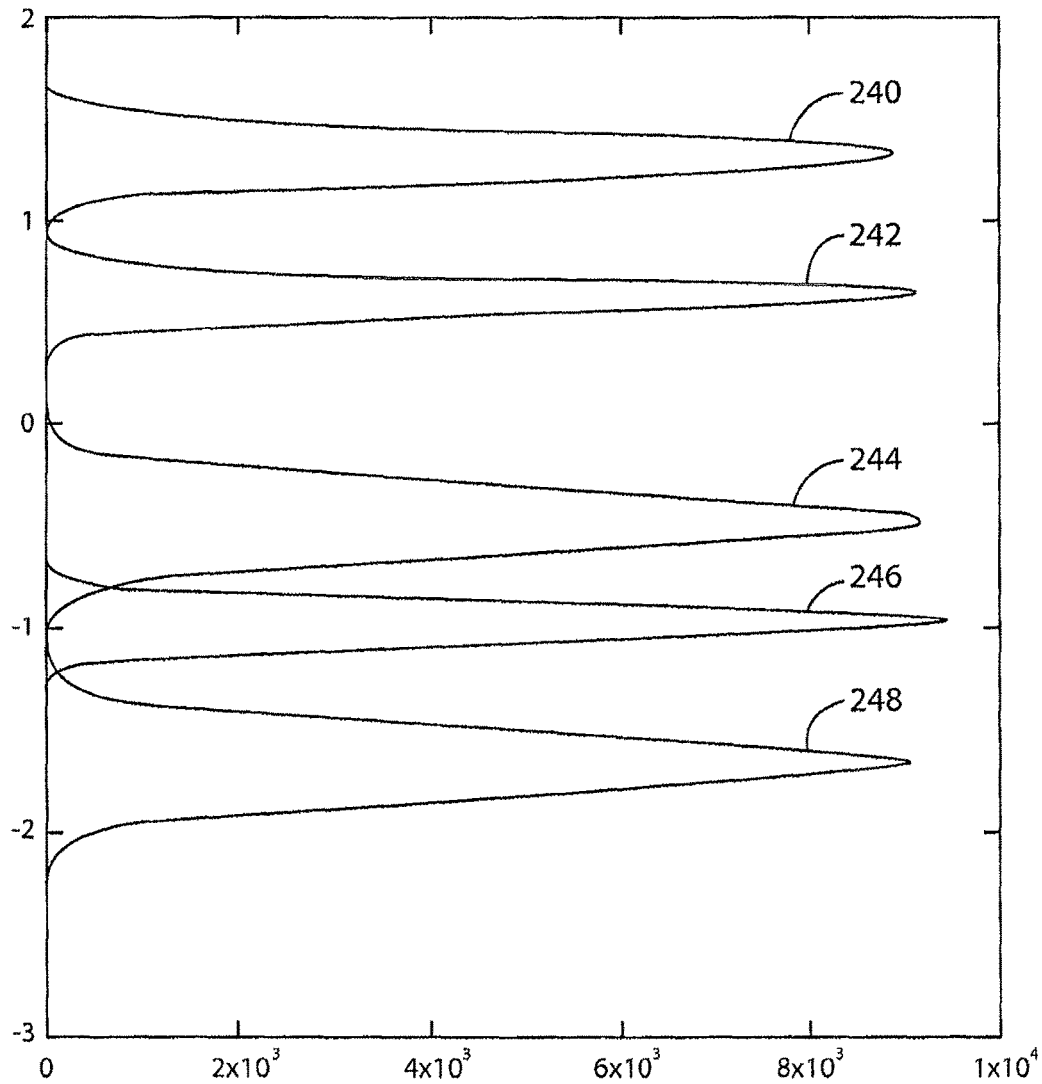


FIG. 11

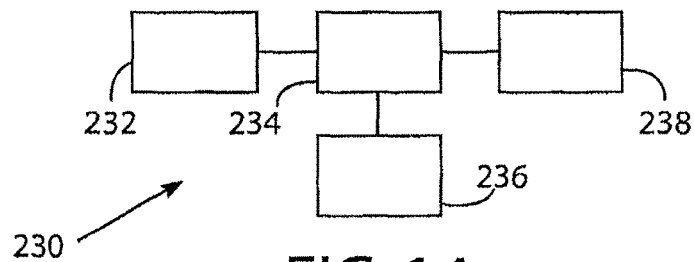


FIG. 14

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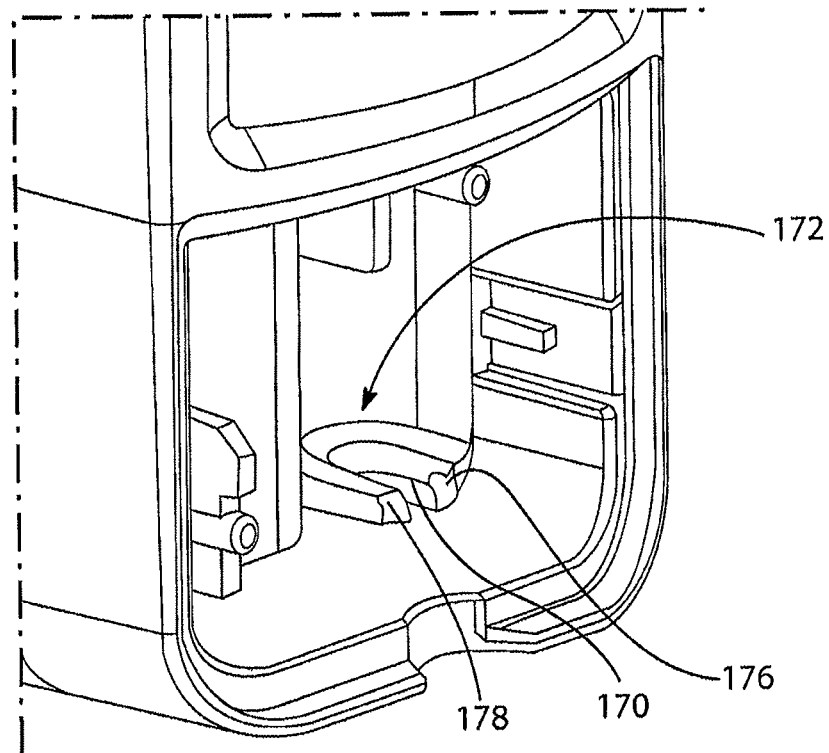


FIG. 12

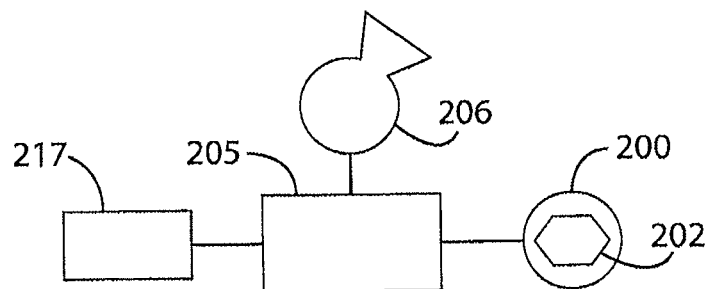
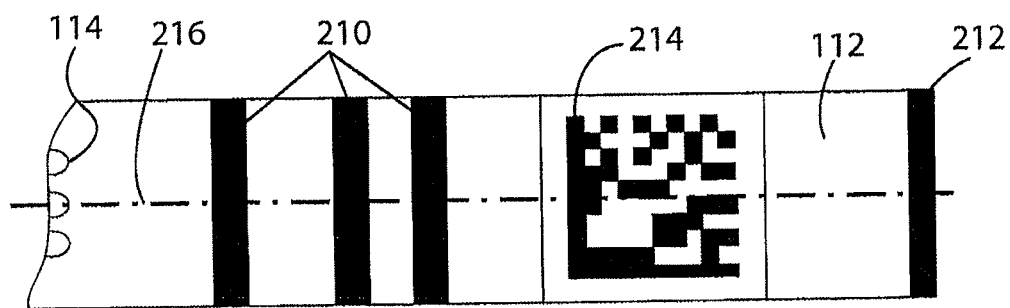


FIG. 13

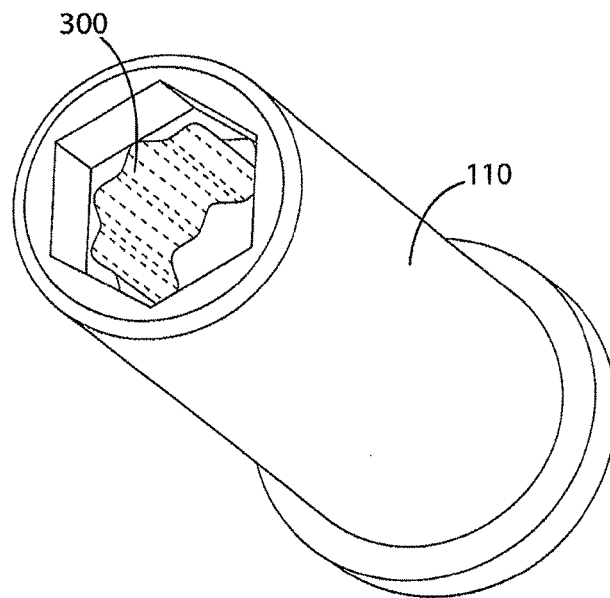


FIG. 15

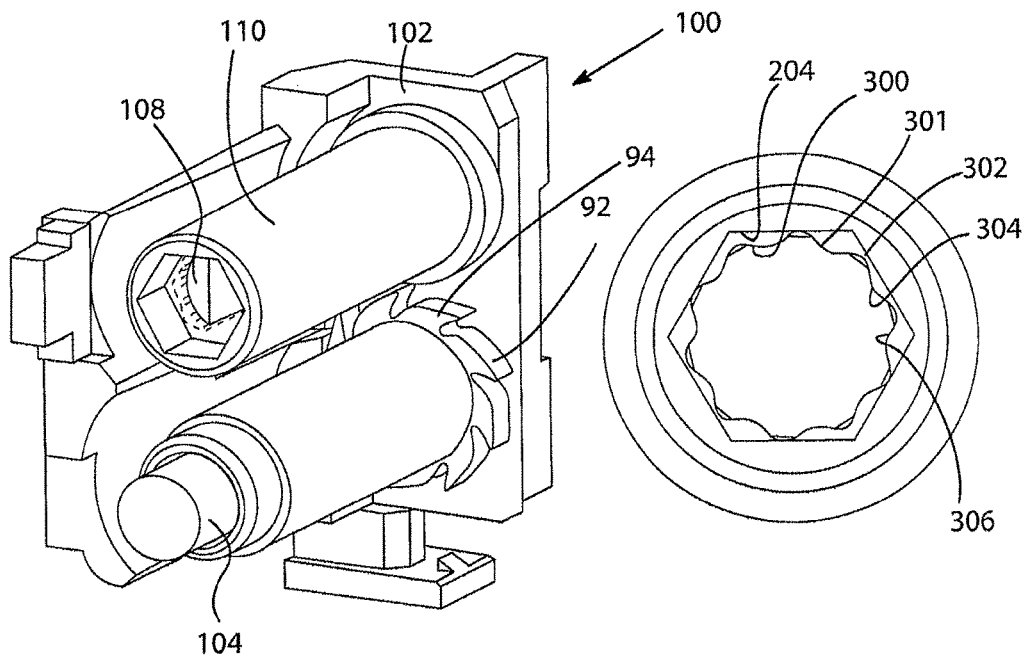


FIG. 20

FIG. 16

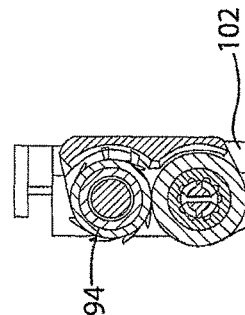


FIG. 19A

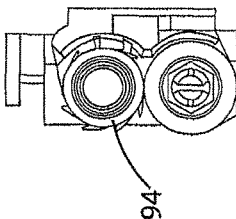


FIG. 19B

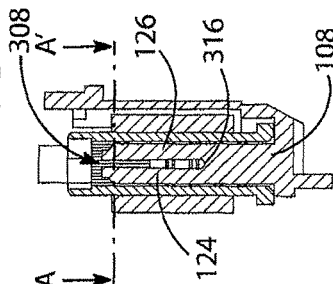


FIG. 19C

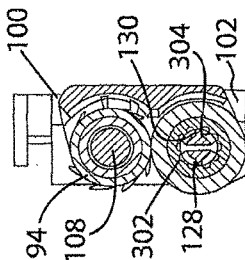


FIG. 18A

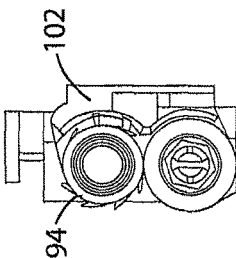


FIG. 18B

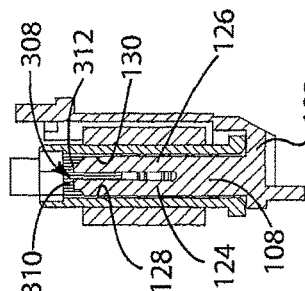


FIG. 18C

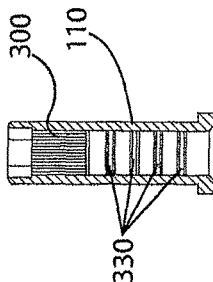
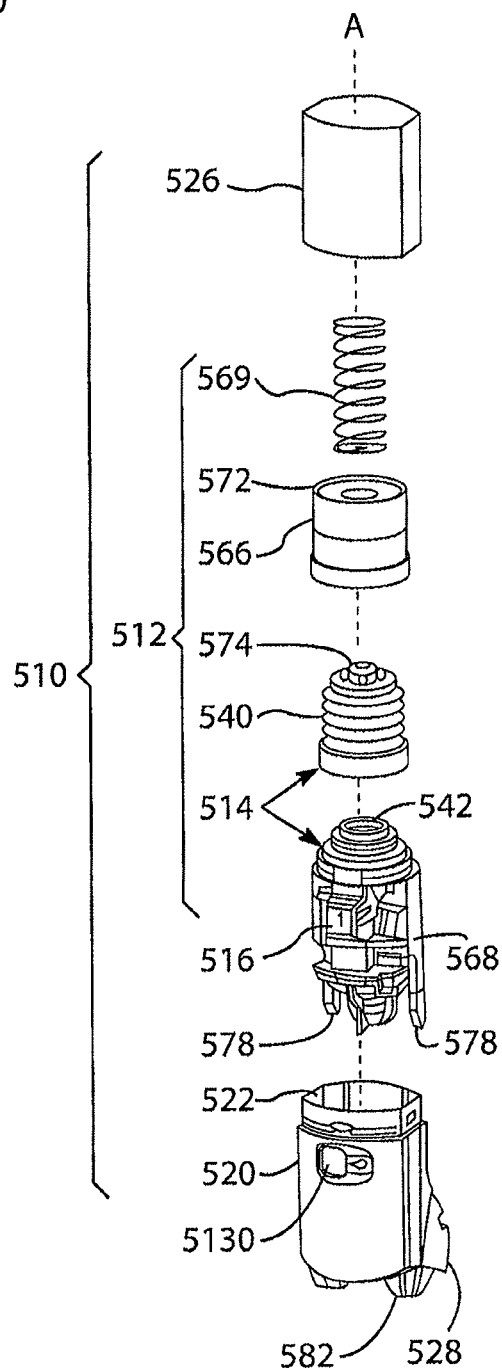
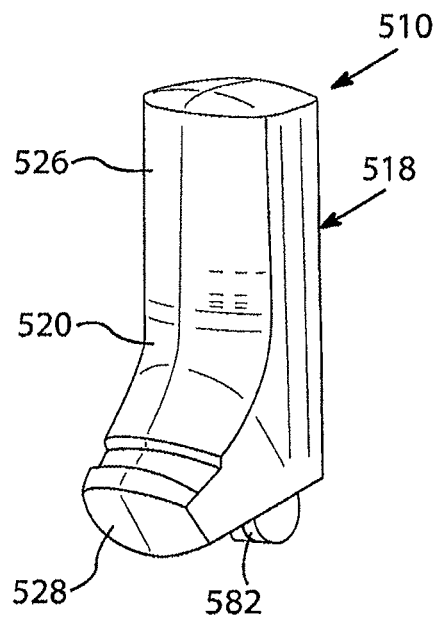


FIG. 17





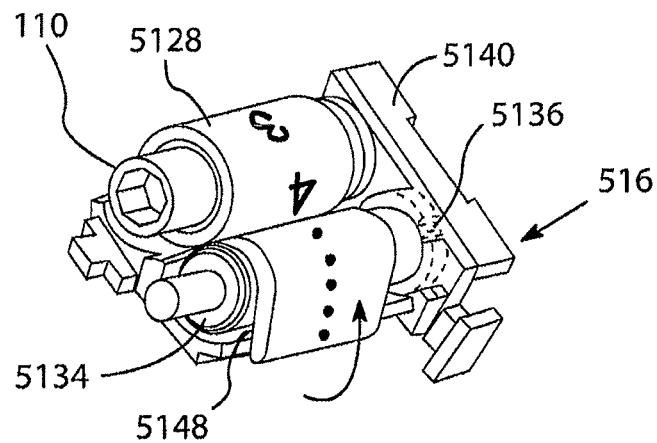


FIG. 23

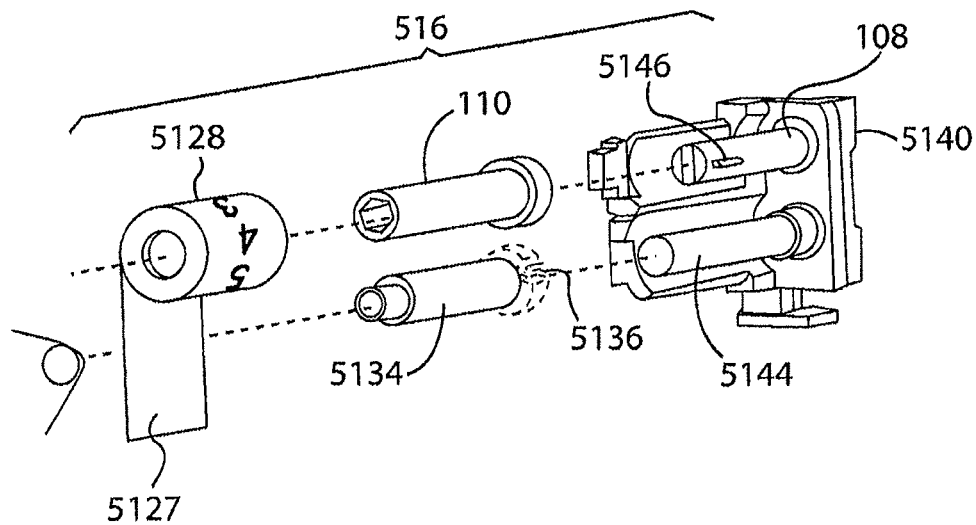


FIG. 24

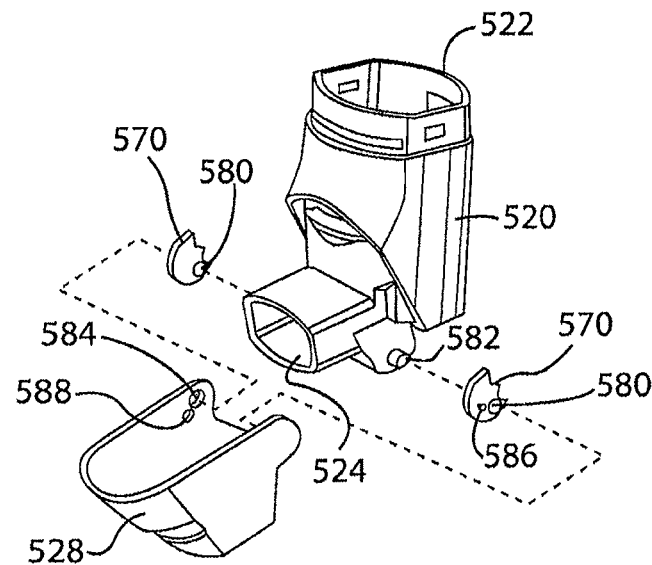


FIG. 25

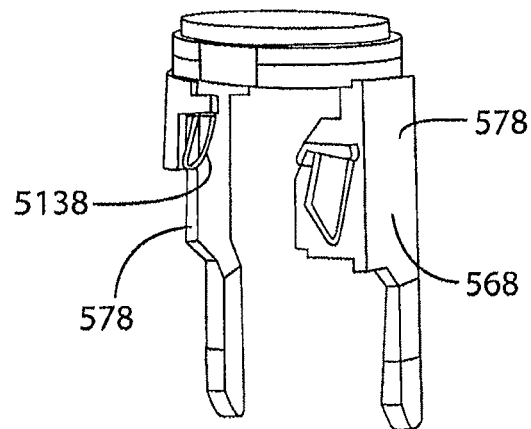


FIG. 26

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# **DOSE COUNTER FOR INHALER AND METHOD FOR COUNTING DOSES**

## **CROSS-REFERENCE TO RELATED APPLICATIONS**

This patent application is a continuation patent application of U.S. Non-Provisional Patent Application No. 14/103,353, filed Dec. 11, 2013, which is a divisional patent application of U.S. Non-Provisional Patent Application No. 13/110,532, filed May 18, 2011, which claims priority to U.S. Provisional Patent Application No. 61/345,763, filed May 18, 2010, and U.S. Provisional Patent Application No. 61/417,659, filed Nov. 29, 2010, each of which is incorporated herein by reference in its entirety for all purposes.

## **FIELD OF THE INVENTION**

The present invention relates to dose counters for inhalers, inhalers and methods of assembly thereof. The invention is particularly applicable to metered dose inhalers including dry power medicament inhalers, breath actuated inhalers and manually operated metered dose medicament inhalers.

## **BACKGROUND OF THE INVENTION**

Metered dose inhalers can comprise a medicament-containing pressurised canister containing a mixture of active drug and propellant. Such canisters are usually formed from a deep-drawn aluminium cup having a crimped lid which carries a metering valve assembly. The metering valve assembly is provided with a protruding valve stem which, in use is inserted as a push fit into a stem block in an actuator body of an inhaler having a drug delivery outlet. In order to actuate a manually operable inhaler, the user applies by hand a compressive force to a closed end of the canister and the internal components of the metering valve assembly are spring loaded so that a compressive force of approximately 15 to 30N is required to activate the device in some typical circumstances.

In response to this compressive force the canister moves axially with respect to the valve stem and the axial movement is sufficient to actuate the metering valve and cause a metered quantity of the drug and the propellant to be expelled through the valve stem. This is then released into a mouthpiece of the inhaler via a nozzle in the stem block, such that a user inhaling through the outlet of the inhaler will receive a dose of the drug.

A drawback of self-administration from an inhaler is that it is difficult to determine how much active drug and/or propellant are left in the inhaler, if any, especially of the active drug and this is potentially hazardous for the user since dosing becomes unreliable and backup devices not always available.

Inhalers incorporating dose counters have therefore become known.

WO 98/028033 discloses an inhaler having a ratchet mechanism for driving a tape drive dose counter. A shaft onto which tape is wound has a friction clutch or spring for restraining the shaft against reverse rotation.

EP-A-1486227 discloses an inhaler for dry powered medicament having a ratchet mechanism for a tape dose counter which is operated when a mouthpiece of the inhaler is closed. Due to the way in which the mouthpiece is opened and closed, and actuation pawl of the device which is mounted on a yoke, travels a known long stroke of consistent length as the mouthpiece is opened and closed.

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WO 2008/119552 discloses a metered-dose inhaler which is suitable for breath-operated applications and operates with a known and constant canister stroke length of 3.04 mm  $\pm$  0.255 mm. A stock bobbin of the counter, from which a tape is unwound, rotates on a shaft having a split pin intended to hold the stock bobbin taut. However, some dose counters do not keep a particularly reliable count, such as if they are dropped onto a hard surface.

More recently, it has become desirable to improve dose counters further and, in particular, it is felt that it would be useful to provide extremely accurate dose counters for manually-operated canister-type metered dose inhalers. Unfortunately, in these inhalers, it has been found in the course of making the present invention that the stroke length of the canister is to a very large extent controlled on each dose operation by the user, and by hand. Therefore, the stroke length is highly variable and it is found to be extremely difficult to provide a highly reliable dose counter for these applications. The dose counter must not count a dose when the canister has not fired since this might wrongly indicate to the user that a dose has been applied and if done repeatedly the user would throw away the canister or whole device before it is really time to change the device due to the active drug and propellant reaching a set minimum. Additionally, the canister must not fire without the dose counter counting because the user may then apply another dose thinking that the canister has not fired, and if this is done repeatedly the active drug and/or propellant may run out while the user thinks the device is still suitable for use according to the counter. It has also been found to be fairly difficult to assembly some known inhaler devices and the dose counters therefor. Additionally, it is felt desirable to improve upon inhalers by making them easily usable after they have been washed with water.

The present invention aims to alleviate at least to a certain extent one or more of the problems of the prior art.

## **SUMMARY OF THE INVENTION**

According to a first aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a counter display arranged to indicate dosage information, a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input, wherein a regulator is provided which is arranged to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

The regulator is advantageous in that it helps prevent unwanted motion of the counter display if the counter is dropped.

According to a further aspect of the present invention, the regulator provides a resistance force of greater than 0.1 N against movement of the counter display. According to still a further aspect of the present invention, the resistance force is greater than 0.3 N. According to yet a further aspect of the present invention, the resistance force is from 0.3 to 0.4 N.

Preferably, the counter comprises a tape.

Preferably, the tape has dose counter indicia displayed thereon. The first station may comprise a region of the dose counter where tape is held which is located before a display location, such as a display window, for the counter indicia.

The first station may comprise a first shaft, the tape being arranged on the first shaft and to unwind therefrom upon movement of the counter display.

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The first shaft may be mounted for rotation relative to a substantially rotationally fixed element of the dose counter.

The regulator may comprise at least one projection which is arranged on one of the first shaft and the substantially rotationally fixed element and to engage incrementally with one or more formations on the other of the first shaft and the substantially rotationally fixed element.

At least two said projections may be provided. Exactly two said projections may be provided.

Each projection may comprise a radiused surface.

The at least one projection may be located on the substantially fixed element which may comprise a fixed shaft which is fixed to a main body of the dose counter, the first shaft being rotationally mounted to the fixed shaft.

Preferably, the fixed shaft has at least two resiliently flexible legs (or forks). Each leg may have at least one said projection formed in an outwardly facing direction thereon, said one or more formations being formed on an inwardly facing engagement surface of the first shaft, said at least one projection being arranged to resiliently engage said one or more formations. Preferably, a series of said formations are provided. An even number of said formations may be provided. Eight to twelve of said formations may be provided. In one embodiment, ten said formations are provided.

Each said formation may comprise a concavity formed on an engagement surface. Each concavity may comprise a radiused surface wall portion which preferably merges on at least one side thereof into a flat wall portion surface. The engagement surface may include a series of said concavities, and convex wall portions of the engagement surface may be formed between each adjacent two said concavities, each said convex wall portion comprising a convex radiused wall portion.

Each convex radiused wall portion of each convex wall portion may be connected by said flat wall portion surfaces to each adjacent concavity.

The fixed shaft may comprise a split pin with fork legs and each projection may be located on a said fork leg.

The first shaft may comprise a substantially hollow bobbin.

Said at least one formation may be located on an inner surface of the bobbin. In other embodiments it may be located on an outer surface thereof. Said engagement surface may extend partially along said bobbin, a remainder of the respective inner or outer surface having a generally smooth journal portion along at least a portion thereof.

The drive system may comprise a tooth ratchet wheel arranged to act upon a second shaft which is located at the second station, the second shaft being rotatable to wind the tape onto the second shaft.

The second shaft may be located on a main body of the dose counter spaced from and parallel to the first shaft.

The ratchet wheel may be fixed to the second shaft is arranged to rotate therewith. The ratchet wheel may be secured to an end of the second shaft and aligned coaxially with the second shaft.

The dose counter may include anti-back drive system which is arranged to restrict motion of the second shaft. The anti-back drive system may include a substantially fixed tooth arranged to act upon teeth of the ratchet wheel.

According to a further aspect of the present invention, a dose counter includes an anti-back drive system which is arranged to restrict motion of the second shaft in a tape winding direction.

According to a further aspect of the present invention there is provided a shaft for holding counter tape in a dose counter for an inhaler, the shaft having an engagement

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surface including incrementally spaced formations located around a periphery thereof, the formations comprising a series of curved concavities and convex portions.

The shaft may comprise a hollow bobbin.

The engagement surface may be a generally cylindrical inwardly directed surface.

The engagement surface may include a flat surface wall portion joining each concavity and convex wall portion.

Each concavity may comprise a radiused wall portion.

Each convex wall portion may comprise a radiused wall portion.

Said concavities may be regularly spaced around a longitudinal axis of the shaft.

Said convex wall portions may be regularly spaced around a longitudinal axis of the shaft.

In some embodiments there may be from eight to twelve said concavities and/or convex wall portions regularly spaced around a longitudinal axis thereof.

One embodiment includes ten said concavities and/or convex wall portions regularly spaced around a longitudinal axis of the shaft.

According to a further aspect of the present invention there is provided a shaft and counter tape assembly for use in a dose counter for an inhaler, the assembly comprising a rotatable shaft and a counter tape which is wound around the shaft and is adapted to unwind therefrom upon inhaler actuation, the shaft having an engagement surface which includes incrementally spaced formations located around a periphery thereof.

According to a further aspect of the present invention there is provided an inhaler for the inhalation of medication and the like, the inhaler including a dose counter as in the first aspect of the present invention.

A preferred construction consists of a manually operated metered dose inhaler including a dose counter chamber including a dose display tape driven by a ratchet wheel which is driven in turn by an actuator pawl actuated by movement of a canister, the tape unwinding from a stock bobbin during use of the inhaler, a rotation regulator being provided for the stock bobbin and comprising a wavelike engagement surface with concavities which engage against control elements in the form of protrusions on resilient forks of a split pin thereby permitting incremental unwinding of the stock bobbin yet resisting excessive rotation if the inhaler is dropped onto a hard surface.

According to another aspect of the present invention there is provided a dose counter for a metered dose inhaler having a body arranged to retain a medicament canister of predetermined configuration for movement of the canister relative thereto; the dose counter comprising: an incremental counting system for counting doses, the incremental counting system having a main body, an actuator arranged to be driven in response to canister motion and to drive an incremental output member in response to canister motion, the actuator and incremental output member being configured to have predetermined canister fire and count configurations in a canister fire sequence, the canister fire configuration being determined by a position of the actuator relative to a datum at which the canister fires medicament and the count configuration being determined by a position of the actuator relative to the datum at which the incremental count system makes an incremental count, wherein the actuator is arranged to reach a position thereof in the count configuration at or after a position thereof in the canister fire configuration.

This arrangement has been found to be highly advantageous since it provides an extremely accurate dose counter

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which is suitable for use with manually operated metered dose inhalers. It has been found that dose counters with these features have a failure rate of less than 50 failed counts per million full canister activation depressions. It has been found in the course of making the present invention that highly reliable counting can be achieved with the dose counter counting at or soon after the point at which the canister fires. It has been is covered by the present inventors that momentum and motion involved in firing the canister, and in some embodiments a slight reduction in canister back pressure on the user at the time of canister firing, can very reliably result in additional further motion past the count point.

The actuator and incremental counting system may be arranged such that the actuator is displaced less than 1 mm, typically 0.25 to 0.75 mm, more preferably about 0.4 to 0.6 mm, relative to the body between its location in the count and fire configurations, about 0.48 mm being preferred. The canister, which can move substantially in line with the actuator, can reliably move this additional distance so as to achieve very reliable counting.

The incremental count system may comprise a ratchet mechanism and the incremental output member may comprise a ratchet wheel having a plurality of circumferentially spaced teeth arranged to engage the actuator.

The actuator may comprise an actuator pawl arranged to engage on teeth of the ratchet wheel. The actuator pawl may be arranged to be connected to or integral with an actuator pin arranged to engage and be depressed by a medicament canister bottom flange. The actuator pawl may be generally U-shaped having two parallel arms arranged to pull on a central pawl member arranged substantially perpendicular thereto. This provides a very reliable actuator pawl which can reliably pull on the teeth of the ratchet wheel.

The incremental count system may include a tape counter having tape with incremental dose indicia located thereon, the tape being positioned on a tape stock bobbin and being arranged to unwind therefrom.

The actuator and incremental output member may be arranged to provide a start configuration at which the actuator is spaced from the ratchet output member, a reset configuration at which the actuator is brought into engagement with the incremental output member during a canister fire sequence, and an end configuration at which the actuator disengages from the ratchet output during a canister fire sequence.

The actuator may be arranged to be located about 1.5 to 2.0 mm, from its location in the fire configuration, when in the start configuration, about 1.80 mm being preferred.

The actuator may be arranged to be located about 1.0 to 1.2 mm, from its location in the fire configuration, when in the reset configuration, about 1.11 mm being preferred.

The actuator may be arranged to be located about 1.1 to 1.3 mm, from its location in the fire configuration, when in the end configuration, about 1.18 mm being preferred.

These arrangements provide extremely reliable dose counting, especially with manually operated canister type metered dose inhalers.

The main body may include a formation for forcing the actuator to disengage from the incremental output member when the actuator is moved past the end configuration. The formation may comprise a bumped up portion of an otherwise generally straight surface against which the actuator engages and along which it is arranged to slide during a canister firing sequence.

The dose counter may include a counter pawl, the counter pawl having a tooth arranged to engage the incremental

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output member, the tooth and incremental output member being arranged to permit one way only incremental relative motion therebetween. When the incremental output member comprises a ratchet wheel, the tooth can therefore serve as an anti-back drive tooth for the ratchet wheel, thereby permitting only one way motion or rotation thereof.

The counter pawl may be substantially fixedly mounted on the main body of the incremental count system and the counter pawl may be arranged to be capable of repeatedly engaging equi-spaced teeth of the incremental output member in anti-back drive interlock configurations as the counter is operated. The counter pawl may be positioned so that the incremental output member is halfway, or substantially halfway moved from one anti-back drive interlock configuration to the next when the actuator and incremental output member are in the end configuration thereof. This is highly advantageous in that it minimises the risk of double counting or non-counting by the dose counter.

According to a further aspect of the invention there is provided an inhaler comprising a main body arranged to retain a medicament canister of predetermined configuration and a dose counter mounted in the main body.

The inhaler main body may include a canister receiving portion and a separate counter chamber, the dose counter being located within the main body thereof, the incremental output member and actuator thereof inside the counter chamber, the main body of the inhaler having wall surfaces separating the canister-receiving portion and the counter chamber, the wall surfaces being provided with a communication aperture, an actuation member extending through the communication aperture to transmit canister motion to the actuator.

According to a further aspect of the present invention there is provided an inhaler for metered dose inhalation, the inhaler comprising a main body having a canister housing arranged to retain a medicament canister for motion therein, and a dose counter, the dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of a medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation located directly adjacent the actuation member.

This is highly advantageous in that the first inner wall canister support formation can prevent a canister from rocking too much relative to the main body of the inhaler. Since the canister may operate the actuation member of the dose counter, this substantially improves dose counting and avoids counter errors.

The canister housing may have a longitudinal axis which passes through a central outlet port thereof, the central outlet port being arranged to mate with an outer canister fire stem of a medicament canister, the inner wall canister support formation, the actuation member and the outlet port lying in a common plane coincident with the longitudinal axis. Accordingly, this construction may prevent the canister from rocking towards the position of the dose counter actuation member, thereby minimising errors in counting.

The canister housing may have a further inner canister wall support formation located on the inner wall opposite, or substantially opposite, the actuation member. Accordingly, the canister may be supported against rocking motion away from the actuator member so as to minimise count errors.

The canister housing may be generally straight and tubular and may have an arrangement in which each said inner wall support formation comprises a rail extending longitudinally along the inner wall.



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Each said rail may be stepped, in that it may have a first portion located towards a medicine outlet end or stem block of the canister housing which extends inwardly a first distance from a main surface of the inner wall and a second portion located toward an opposite end of the canister chamber which extends inwardly a second, smaller distance from the main surface of the inner wall. This may therefore enable easy insertion of a canister into the canister housing such that a canister can be lined up gradually in step wise function as it is inserted into the canister housing.

The inhaler may include additional canister support rails which are spaced around an inner periphery of the inner wall of the canister housing and which extend longitudinally therealong.

At least one of the additional rails may extend a constant distance inwardly from the main surface of the inner wall.

At least one of the additional rails may be formed with a similar configuration to the first inner wall canister support formation.

The dose counter may, apart from said at least a portion of the actuation member, be located in a counter chamber separate from the canister housing, the actuation member comprising a pin extending through an aperture in a wall which separates the counter chamber and the canister housing.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicaments having: a body for retaining a medicament store; the body including a dose counter, the dose counter having a moveable actuator and a return spring for the actuator, the return spring having a generally cylindrical and annular end; the body having a support formation therein for supporting said end of the return spring, the support formation comprising a shelf onto which said end is engageable and a recess below the shelf.

This shelf and recess arrangement is highly advantageous since it allows a tool (such as manual or mechanical tweezers) to be used to place the return spring of the actuator onto the shelf with the tool then being withdrawn at least partially via the recess.

The shelf may be U-shaped.

The support formation may include a U-shaped upstanding wall extending around the U-shaped shelf, the shelf and upstanding wall thereby forming a step and riser of a stepped arrangement.

The recess below the shelf may also be U-shaped.

At least one chamfered surface may be provided at an entrance to the shelf. This may assist in inserting the actuator and return spring into position.

A further aspect of the invention provides a method of assembly of an inhaler which includes the step of locating said end of said spring on the shelf with an assembly tool and then withdrawing the assembly tool at least partly via the recess. This assembly method is highly advantageous compared to prior art methods in which spring insertion has been difficult and in which withdrawal of the tool has sometimes accidentally withdrawn the spring again.

The cylindrical and annular end of the spring may be movable in a direction transverse to its cylindrical extent into the shelf while being located thereon.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament, the inhaler having a body for retaining a medicament store; and a dose counter, the dose counter having a moveable actuator and a chassis mounted on the body; the chassis being heat staked in position on the body. This is highly advantageous in that the chassis can be very accurately positioned

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and held firmly in place, thereby further improving counting accuracy compared to prior art arrangements in which some movement of the chassis relative to the body may be tolerated in snap-fit connections.

The chassis may have at least one of a pin or aperture heat staked to a respective aperture or pin of the body.

The chassis may have a ratchet counter output member mounted thereon.

The ratchet counter output member may comprise a ratchet wheel arranged to reel in incrementally a dose meter tape having a dosage indicia located thereon.

According to a further aspect of the present invention there is provided a method of assembling an inhaler including the step of heat staking the chassis onto the body. The step of heat staking is highly advantageous in fixedly positioning the chassis onto the body in order to achieve highly accurate dose counting in the assembled inhaler.

The method of assembly may include mounting a spring-retained ratchet actuator in the body before heat staking the chassis in place. The method of assembly may include pre-assembling the chassis with a dose meter tape prior to the step of heat staking the chassis in place. The method of assembly may include attaching a dose meter cover onto the body after the heat staking step. The cover may be welded onto the body or may in some embodiments be glued or otherwise attached in place.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament and having a body, the body have a main part thereof for retaining a medicament store; and a dose counter, the dose counter being located in a dose counter chamber of the body which is separated from the main part of the body, the dose counter chamber of the body having a dosage display and being perforated so as to permit the evaporation of water or aqueous matter in the dose counter chamber into the atmosphere.

This is highly advantageous since it enables the inhaler to be thoroughly washed and the dose counting chamber can thereafter dry out fully.

The display may comprise a mechanical counter display inside the dose counter chamber and a window for viewing the mechanical counter display. The mechanical counter display may comprise a tape. The perforated dose counter chamber may therefore enable reliable washing of the inhaler, if desired by the user, and may therefore dry out without the display window misting up.

The dose counter chamber may be perforated by a drain hole formed through an outer hole of the body. The drain hole may be located at a bottom portion of the body of the inhaler, thereby enabling full draining of the inhaler to be encouraged after washing when the inhaler is brought into an upright position.

According to a further aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a display tape arranged to be incrementally driven from a tape stock bobbin onto an incremental tape take-up drive shaft, the bobbin having an internal bore supported by and for rotation about a support shaft, at least one of the bore and support shaft having a protrusion which is resiliently biased into frictional engagement with the other of the bore and support shaft with longitudinally extending mutual frictional interaction. This arrangement may provide good friction for the bobbin, thereby improving tape counter display accuracy and preventing the bobbin from unwinding undesirably for example if the inhaler is accidentally dropped.



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The support shaft may be forked and resilient for resiliently biasing the support shaft and bore into frictional engagement.

The support shaft may have two forks, or more in some cases, each having a radially extending protrusion having a friction edge extending therealong parallel to a longitudinal axis of the support shaft for frictionally engaging the bore of the support shaft with longitudinally extending frictional interaction therebetween.

The bore may be a smooth circularly cylindrical or substantially cylindrical bore.

Each of the above inhalers in accordance with aspects of the present invention may have a medicament canister mounted thereto.

The canister may comprise a pressurised metered dose canister having a reciprocally movable stem extending therefrom and movable into a main canister portion thereof for releasing a metered dose of medicament under pressure, for example by operating a metered dose valve inside the canister body. The canister may be operable by pressing by hand on the main canister body.

In cases in which one or more support rails or inner wall support formations are provided, the canister may at all times when within the canister chamber have a clearance of about 0.25 to 0.35 mm from the first inner wall support formation. The clearance may be almost exactly 0.3 mm. This clearance which may apply to the canister body itself or to the canister once a label has been applied, is enough to allow smooth motion of the canister in the inhaler while at the same time preventing substantial rocking of the canister which could result in inaccurate counting by a dose counter of the inhaler, especially when lower face of the canister is arranged to engage an actuator member of the dose counter for counting purposes.

According to a further aspect of the invention, a method of assembling a dose counter for an inhaler comprises the steps of providing a tape with dosing indicia thereon; providing tape positioning indicia on the tape; and stowing the tape while monitoring for the tape positioning indicia with a sensor. The method advantageously permits efficient and accurate stowing of the tape, e.g. by winding.

The dosing indicia may be provided as numbers, the tape positioning indicia may be provided as one or more lines across the tape. The stowing step comprises winding the tape onto a bobbin or shaft, and, optionally, stopping winding when the positioning indicia are in a predetermined position. The tape may be provided with pixelated indicia at a position spaced along the tape from the positioning indicia. The tape may also be provided with a priming dot.

According to a further aspect of the invention, a tape system for a dose counter for an inhaler has a main elongate tape structure, and dosing indicia and tape positioning indicia located on the tape structure. The tape positioning indicia may comprise at least one line extending across the tape structure. The tape system may comprise pixelated indicia located on the tape structure and spaced from the positioning indicia. The tape system may comprise a priming dot located on the tape structure. The positioning indicia may be located between the timing dot and the pixelated indicia. The main elongate tape structure may have at least one end thereof wound on a bobbin or shaft.

A further aspect of the invention provides a method of designing an incremental dose counter for an inhaler comprising the steps of calculating nominal canister fire and dose counter positions for a dose counter actuator of the inhaler; calculating a failure/success rate for dose counters built to tolerance levels for counting each fire of inhalers in

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which the dose counter actuators may be applied; and selecting a tolerance level to result in said failure/success rate to be at or below/above a predetermined value. This is highly advantageous in that it allows an efficient and accurate prediction of the reliability of a series of inhaler counters made in accordance with the design.

The method of designing may include selecting the failure/success rate as a failure rate of no more than one in 50 million. The method of designing may include setting an average count position for dose counters built to the tolerances to be at or after an average fire position thereof during canister firing motion. The method of designing may include setting the average count position to be about 0.4 to 0.6 mm after the average fire position, such as about 0.48 mm after. The method of designing may include setting tolerances for the standard deviation of the fire position in dose counters built to the tolerances to be about 0.12 to 0.16 mm, such as about 0.141 mm. The method of designing may include setting tolerances for the standard deviation of the count positions in dose counters built to the tolerances to be about 0.07 to 0.09 mm, such as about 0.08 mm. A further aspect of the invention provides a computer implemented method of designing an incremental dose counter for an inhaler which includes the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing in a production run a series of incremental dose counters for inhalers which comprises manufacturing the series of dose counters in accordance with the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing a series of incremental dose counters for inhalers, which comprises manufacturing the dose counters with nominal canister fire and dose count positions of a dose counter actuator relative to a dose counter chassis (or inhaler main body), and which includes building the dose counters with the average dose count position in the series being, in canister fire process, at or after the average canister fire position in the series.

According to a further aspect of the invention, the method provides fitting each dose counter in the series of incremental dose counters to a corresponding main body of an inhaler.

These aspects advantageously provide for the production run of a series of inhalers and dose counters which count reliably in operation.

According to a further aspect of the invention, an incremental dose counter for a metered dose inhaler has a body arranged to retain a canister for movement of the canister relative thereto, the incremental dose counter having a main body, an actuator arranged to be driven and to drive an incremental output member in a count direction in response to canister motion, the actuator being configured to restrict motion of the output member in a direction opposite to the count direction. This advantageously enables an inhaler dose counter to keep a reliable count of remaining doses even if dropped or otherwise jolted.

The output member may comprise a ratchet wheel. The actuator may comprise a pawl and in which the ratchet wheel and pawl are arranged to permit only one-way ratcheting motion of the wheel relative to the pawl. The dose counter may include an anti-back drive member fixed to the main body. In a rest position of the dose counter, the ratchet wheel is capable of adopting a configuration in which a back surface of one tooth thereof engages the anti-back drive member and the pawl is spaced from an adjacent back

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surface of another tooth of the ratchet wheel without positive drive/blocking engagement between the pawl and wheel.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be carried out in various ways and preferred embodiment of a dose counter, inhaler and methods of assembly, design and manufacture will now be described with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of a main body of an embodiment of an inhaler related to the invention together with a mouthpiece cap therefor;

FIG. 2 is a top plan view of the components as shown in FIG. 1;

FIG. 3A is a section on the plane 3A-3A in FIG. 2;

FIG. 3B is a view corresponding to FIG. 3A but with a dose counter fitted to the main body of the inhaler;

FIG. 4A is an exploded view of the inhaler main body, mouthpiece cap, dose counter and a dose counter window;

FIG. 4B is a view in the direction 4B in FIG. 4C of a spring retainer of the dose counter;

FIG. 4C is a top view of the spring retainer of FIG. 4B;

FIG. 5 is a bottom view of the assembled inhaler main body, mouthpiece cap, dose counter and dose counter window;

FIGS. 6A, 6B, 6C, 6D, 6E, 6F, 6G and 6H are various views of dose counter components of the inhaler;

FIGS. 7A and 7B are sectional views showing canister clearance inside the main body of the inhaler;

FIG. 7C is a further sectional view similar to that of FIG. 7B but with the canister removed;

FIG. 7D is a top plan view of the inhaler main body;

FIGS. 8A, 8B, 8C and 8D show the inhaler main body and dose counter components during assembly thereof;

FIG. 9 shows a sectional side view of a datum line for an actuator pawl of the dose counter;

FIGS. 10A, 10B, 10C, 10D, 10E and 10F show various side views of positions and configurations of the actuator pawl, a ratchet wheel, and a count pawl;

FIG. 11 shows distributions for tolerances of start, reset, fire, count and end positions for the actuator of the dose counter;

FIG. 12 is an enlarged version of part of FIG. 4A;

FIG. 13 shows an end portion of a tape of the dose counter;

FIG. 14 shows a computer system for designing the dose counter;

FIG. 15 is an isometric view of a stock bobbin modified in accordance with the present invention for use in the dose counter of the inhaler of FIGS. 1 to 14;

FIG. 16 shows an end view of the stock bobbin of FIG. 15;

FIG. 17 is a section through a longitudinal axis of the stock bobbin of FIGS. 15 and 16;

FIGS. 18A, 18B and 18C are views of the stock bobbin of FIGS. 15 to 17 mounted in the dose counter chassis of FIGS. 1 to 14, with the control elements of the forks of the second shaft (or split pin) having a profile slightly different to that in FIG. 6F, with the forks in a compressed configuration;

FIGS. 19A, 19B and 19C are views equivalent to FIGS. 18A to 18C but with the forks in a more expanded configuration due to a different rotational position of the stock bobbin;

FIG. 20 is an isometric view of the chassis assembled and including the stock bobbin of FIGS. 15 to 17 but excluding the tape for reasons of clarity;

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FIG. 21 is a view of a preferred embodiment of a dry powder inhaler in accordance with the present invention;

FIG. 22 is an exploded view of the inhaler of FIG. 21;

FIG. 23 is a view of a dose counter of the inhaler of FIG. 21;

FIG. 24 is an exploded view of the dose counter shown in FIG. 23;

FIG. 25 is an exploded view of parts of the inhaler of FIG. 21; and

FIG. 26 is a view of a yoke of the inhaler of FIG. 21.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a main body 10 of a manually operated metered dose inhaler 12 in accordance with an embodiment related to the present invention and having a mouthpiece cap 14 securable over a mouthpiece 16 of the main body.

The main body has a canister chamber 18 into which a canister 20 (FIG. 7A) is slideable. The canister 20 has a generally cylindrical main side wall 24, joined by a tapered section 26 to a head portion 28 having a substantially flat lower face 30 which has an outer annular drive surface 32 arranged to engage upon and drive an actuation pin 34 of a dose counter 36 as will be described. Extending centrally and axially from the lower face 30 is a valve stem 38 which is arranged to sealingly engage in a valve stem block 40 of the main body 10 of the inhaler 12. The valve stem block 40 has a passageway 42 leading to a nozzle 44 for directing the contents of the canister 20, namely active drug and propellant, towards an air outlet 46 of the inhaler main body 12. It will be appreciated that due to gaps 48 between the canister 20 and an inner wall 50 of the main body 10 of the inhaler 12 an open top 52 of the main body 10 forms an air inlet into the inhaler 12 communicating via air passageway 54 with the air outlet 46, such that canister contents exiting nozzle 44 mix with air being sucked by the user through the air passageway 54 in order to pass together through the air outlet and into the mouth of the user (not shown).

The dose counter 36 will now be described. The dose counter 36 includes an actuation pin 34 biased upwardly from underneath by a return spring 56 once installed in the main body 10. As best shown in FIGS. 4A, 6H and 8A, the pin 34 has side surfaces 58, 60 arranged to slide between corresponding guide surfaces 62, 64 located in a dose counter chamber 66 of the main body 10, as well as an end stop surface 68 arranged to engage a corresponding end stop 70 formed in the dose counter chamber 66 to limit upward movement of the pin 34. The pin 34 has a top part 72 which is circularly cylindrical and extends through an aperture 74 formed through a separator wall 76 which separates the canister chamber 18 from the dose counter chamber 66. The top part 72 of the pin 34 has a flat top surface 78 which is arranged to engage the outer annular drive surface 32 of the canister 20.

The actuation pin 34 is integrally formed with a drive or actuator pawl 80. The actuator pawl 80 has a generally inverted U-shape configuration, having two mutually spaced and parallel arms 82, 84 extending from a base portion of the actuation pin 34, each holding at respective distal ends 88 thereof opposite ends of a pawl tooth member 90 which extends in a direction substantially perpendicular to the arms 82, 84, so as to provide what may be considered a "saddle" drive for pulling on each of the 11 drive teeth 92 of a ratchet wheel 94 of an incremental drive system 96 or ratchet mechanism 96 of the dose counter 36. As shown for example in FIG. 10B, the pawl tooth member 90 has a sharp lower

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longitudinal side edge 98 arranged to engage the drive teeth 92, the edge-to-surface contact provided by this engagement providing very accurate positioning of the actuator pawl 80 and resultant rotational positioning of the ratchet wheel 94.

The dose counter 36 also has a chassis preassembly 100 which, as shown in FIGS. 4A and 6A, includes a chassis 102 having a first shaft 104 receiving the ratchet wheel 94 which is secured to a tape reel shaft 106, and a second shaft (or split pin) 108 which is parallel to and spaced from the first shaft 104 and which slidably and rotationally receives a tape stock bobbin 110.

As shown in FIG. 6B, when the inhaler has not been used at all, the majority of a tape 112 is wound on the tape stock bobbin 110 and the tape 112 has a series of regularly spaced numbers 114 displayed therealong to indicate a number of remaining doses in the canister 20. As the inhaler is repeatedly used, the ratchet wheel 94 is rotated by the actuator pawl 80 due to operation of the actuation pin 34 by the canister 20 and the tape 112 is incrementally and gradually wound on to the tape reel shaft 106 from the second shaft 108. The tape 112 passes around a tape guide 116 of the chassis 102 enabling the numbers 114 to be displayed via a window 118 in a dose counter chamber cover 120 having a dose marker 132 formed or otherwise located thereon.

As shown in FIGS. 6A and 6D, the second shaft 108 is forked with two forks 124, 126. The forks 124, 126 are biased away from one another. The forks have located thereon at diametrically opposed positions on the second shaft 108 friction or control elements 128, 130, one on each fork. Each control element extends longitudinally along its respective fork 124, 126 and has a longitudinally extending friction surface 132, 134 which extends substantially parallel to a longitudinal axis of the second shaft and is adapted to engage inside a substantially cylindrical bore 136 inside the tape stock bobbin 110. This control arrangement provided between the bore 136 and the control elements 128, 130 provides good rotational control for the tape stock bobbin 110 such that it does not unwind undesirably such as when the inhaler is dropped. The tape force required to unwind the tape stock bobbin 110 and overcome this friction force is approximately 0.1 N.

As can be seen in FIG. 6D, as well as FIGS. 6G and 10A to 10F, the chassis 102 is provided with an anti-back drive tooth 138 or count pawl 138 which is resiliently and substantially fixedly mounted thereto. As will be described below and as can be seen in FIGS. 10A to 10F, when the actuation pin 34 is depressed fully so as to fire the metered valve (not shown) inside the canister 20, the actuator pawl 80 pulls down on one of the teeth 92 of the ratchet wheel 94 and rotates the wheel 94 anticlockwise as shown in FIG. 6D so as to jump one tooth 92 past the count pawl 138, thereby winding the tape 112 a distance incrementally relative to the dose marker 122 on the dose counter chamber 120 so as to indicate that one dose has been used.

With reference to FIG. 10B, the teeth of the ratchet wheel 94 have tips 143 which are radiused with a 0.1 mm radius between the flat surfaces 140, 142. The ratchet wheel 94 has a central axis 145 which is 0.11 mm above datum plane 220 (FIG. 9). A top/nose surface 147 of the anti-back drive tooth 138 is located 0.36 mm above the datum plane 220. The distance vertically (i.e. transverse to datum plane 220—FIG. 9) between the top nose surface 147 of the anti-back drive tooth is 0.25 mm from the central axis 145 of the wheel 94. Bump surface 144 has a lateral extent of 0.20 mm, with a vertical length of a flat 145' thereof being 1 mm, the width of the bump surface being 1.22 mm (in the direction of the axis 145), the top 149 of the bump surface 144 being 3.02

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mm vertically below the axis 145, and the flat 145' being spaced a distance sideways (i.e. parallel to the datum plane 220) 2.48 mm from the axis 145. The top surface 78 of the pin 34 (FIG. 6H) is 11.20 mm above the datum plane 220 (FIG. 9) when the actuator pawl 80 and pin 34 are in the start configuration. The length of the valve stem 22 is 11.39 mm and the drive surface 32 of the canister 20 is 11.39 mm above the datum plane 220 when the canister is at rest waiting to be actuated, such that there is a clearance of 0.19 mm between the canister 20 and the pin 34 in this configuration.

FIGS. 10A and 10B show the actuator pawl 80 and ratchet wheel 94 and count pawl 138 in a start position in which the flat top 78 of the pin 34 has not yet been engaged by the outer annular drive surface 32 of the canister 20 or at least has not been pushed down during a canister depression.

In this "start" position, the count pawl 138 engages on a non-return back surface 140 of one of the teeth 92 of the ratchet wheel 94. The lower side edge 98 of the actuator pawl is a distance "D" (FIG. 9) 1.33 mm above datum plane 220 which passes through bottom surface or shoulder 41 of valve stem block 40, the datum plane 220 being perpendicular to a main axis "X" of the main body 10 of the inhaler 12 which is coaxial with the centre of the valve stem block bore 43 and parallel to a direction of sliding of the canister 20 in the main body 10 of the inhaler 12 when the canister is fired.

As shown in FIG. 10B, an advantageous feature of the construction is that the pawl tooth/actuator 90 acts as a supplementary anti-back drive member when the inhaler 12 is not being used for inhalation. In particular, if the inhaler 12 is accidentally dropped, resulting in a jolt to the dose counter 36 then, if the wheel 94 would try to rotate clockwise (backwards) as shown in FIG. 10B, the back surface 140 of a tooth will engage and be blocked by the tooth member 90 of the pawl 80. Therefore, even if the anti-back drive tooth 138 is temporarily bent or overcome by such a jolt, undesirable backwards rotation of the wheel 94 is prevented and, upon the next canister firing sequence, the pawl 90 will force the wheel 94 to catch up to its correct position so that the dose counter 36 continues to provide correct dosage indication.

FIG. 10C shows a configuration in which the actuator pawl 80 has been depressed with the pin 34 by the canister 20 to a position in which the side edge 98 of the pawl tooth member 90 is just engaged with one of the teeth 92 and will therefore upon any further depression of the pin 34 begin to rotate the wheel 94. This is referred to as a "Reset" position or configuration. In this configuration, the lower side edge 98 of the actuator 80 is 0.64 mm above the datum plane 220.

FIG. 10D shows a configuration in which the actuator pawl 80 has been moved to a position lower than that shown in FIG. 10C and in which the metered dose valve (not shown) inside the canister has at this very position fired in order to eject active drug and propellant through the nozzle 44. It will be noted that in this configuration the count pawl 138 is very slightly spaced from the back surface 140 of the same tooth 92 that it was engaging in the configuration of FIG. 10D. The configuration shown in FIG. 10D is known as a "Fire" configuration. In this configuration the lower side edge 98 of the actuator 80 is 0.47 mm below the datum plane 220.

FIG. 10E shows a further step in the sequence, called a "Count" position in which the actuator pawl 80 has rotated the ratchet wheel 94 by the distance circumferentially angularly between two of the teeth 92, such that the count pawl 138 has just finished riding along a forward surface 142 of one of the teeth 92 and has resiliently jumped over the tooth



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into engagement with the back surface **140** of the next tooth. Accordingly, in this "Count" configuration, a sufficiently long stroke movement of the pin **34** has occurred that the tape **112** of the dose counter **36** will just have counted down one dose. In this configuration, the lower side edge **98** of the actuator is 0.95 mm below the datum plane **220**. Accordingly, in this position, the actuator **80** generally, including edge **98**, is 0.48 mm lower than in the fire configuration. It has been found that, although the count configuration happens further on than the fire configuration, counting is highly reliable, with less than 50 failed counts per million. This is at least partially due to momentum effects and to the canister releasing some back pressure on the user in some embodiments as its internal metering valve fires.

In the configuration of FIG. **10F**, the pawl **80** has been further depressed with the pin **34** by the canister **20** to a position in which it is just disengaging from one of the teeth **92** and the actuator pawl **80** is assisted in this disengagement by engagement of one of the arms **84** with a bump surface **144** on the chassis **102** (see FIG. **6G**) and it will be seen at this point of disengagement, which is called an "End" configuration, the count pawl **138** is positioned exactly halfway or substantially halfway between two of the drive teeth **92**. This advantageously means therefore that there is a minimum chance of any double counting or non-counting, which would be undesirable. In the end configuration, the side edge **98** of the actuator is 1.65 mm below the datum plane **220**. It will be appreciated that any further depression of the actuator pawl **80** and pin **34** past the "End" configuration shown in FIG. **10F** will have no effect on the position of the tape **112** displayed by the dose counter **36** since the actuator pawl **80** is disengaged from the ratchet wheel **94** when it is below the position shown in FIG. **10F**.

As shown in FIGS. **7C** and **7D**, the inner wall **50** of the main body **10** is provided with a two-step support rail **144** which extends longitudinally along inside the main body and is located directly adjacent the aperture **74**. As shown in FIG. **7B** a diametrically opposed two-step support rail **146** is also provided and this diametrically opposed in the sense that a vertical plane (not shown) can pass substantially directly through the first rail **144**, the aperture **74**, a central aperture **148** of the valve stem block **40** (in which canister stem **25** is located) and the second two-step support rail **146**. As shown in FIG. **7A** and schematically in FIG. **7B**, the rails **144**, **146** provide a maximum clearance between the canister **20** and the rails **144**, **146** in a radial direction of almost exactly 0.3 mm, about 0.25 to 0.35 mm being a typical range. This clearance in this plane means that the canister **20** can only rock backwards and forwards in this plane towards away from the actuation pin **34**. A relatively small distance and this therefore prevents the canister wobbling and changing the height of the actuation pin **34** as to undesirably alter the accuracy of the dose counter **36**. This is therefore highly advantageous.

The inner wall **50** of the main body **10** is provided with two further two-step rails **150** as well as two pairs **152**, **154** of rails extending different constant radial amounts inwardly from the inner wall **50**, so as to generally achieve a maximum clearance of almost exactly 0.3 mm around the canister **20** for all of the rails **144**, **146**, **150**, **152**, **154** spaced around the periphery of the inner wall **50**, in order to prevent undue rocking while still allowing canister motion freely inside the inhaler **12**. It will be clear from FIG. **7C** for example that the two-step rails have a first portion near an outlet end **156** of the canister chamber **18**, the first portion having a substantially constant radial or inwardly-extending width, a first step **160** leading to a second portion **162** of the rail, the

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second portion **102** having a lesser radial or inwardly extending extent than the first portion **156**, and finally a second step **164** at which the rail merges into the main inner wall **50** main surface.

A method of assembling the inhaler **12** will now be described.

With reference to FIG. **8A**, the main body **10** of the inhaler **12** is formed by two or more plastics mouldings which have been joined together to the configuration shown.

As shown in FIG. **8B**, the actuator pawl **80** and pin **34** are translated forward into position into a pin receiving area **166** in the dose counter chamber **66** and the pin **34** and actuator **80** may then be raised until the pin **34** emerges through the aperture **74**.

Next, the return spring **56** may be inserted below the pin **34** and a generally cylindrical annular lower end **168** of the spring **56** may be moved by a tweezer or tweezer-like assembly tool (not shown) into engagement with a shelf **170** of a spring retainer **172** in the dose counter chamber **66**. The spring retainer **172** is U-shaped and the shelf **170** is U-shaped and has a recess **174** formed below it. As shown in FIGS. **4B**, **4C** and **12** shelf **170** includes three chamfer surfaces **176**, **178**, **180** arranged to assist in moving the lower end of the spring **168** into position onto the shelf using the assembly tool (not shown). Once the lower end of the spring **168** is in place, the assembly tool (not shown) can easily be removed at least partly via the recess **174** below the lower end **168** of the spring **56**.

The tape **112** is attached at one end (not shown) to the tape stock bobbin **110** and is wound onto the bobbin by a motor **200** (FIG. **13**) having a hexagonal output shaft **202** which engages in a hexagonal socket **204** (FIG. **6B**) of the bobbin. During winding, the tape is monitored by a sensor **206**, which may be in the form of a camera or laser scanner, which feeds data to a computer controller **205** for the motor **200**. The controller **205** recognises three positioning markers **210** in the form of lines across the tape **112** and stops the motor **202** when the tape **112** is nearly fully wound onto the bobbin **110**, such that the distal end **212** of the tape **112** can be secured, e.g. by adhesive, to the tape reel shaft **106**. The controller **205** also recognises a pixelated tape size marker **214** observed by the sensor **206** and logs in a stocking system data store **217** details of the tape **112** such as the number of numbers **114** on the tape, such as one hundred and twenty or two hundred numbers **114**. Next, the tape reel shaft is wound until an appropriate position of the lines **210** at which a priming dot **216** will, once the bobbin **110** and reel shaft **106** are slid onto the second shaft **108** and second shaft **104**, be in a position to be located in the window **118** when the inhaler **12** is fully assembled. In the embodiments, the bobbin **110** and reel shaft **106** may be slid onto the shafts **108**, **104** before the tape **112** is secured to the reel shaft **106** and the reel shaft may then be wound to position the priming dot **216**.

Next, the assembled dose counter components of the chassis preassembly **100** shown in FIG. **6B** may as shown in FIG. **8C** be inserted into the dose counter chamber **66**, with pins **182**, **184**, **186** formed on the main body **10** in the dose counter chamber **66** passing through apertures or slots **188**, **190**, **192** formed on the chassis **102**, such that the pins **182**, **184**, **186** extend through (or at least into) the apertures or slots **188**, **190**, **192**. With the chassis **102** being relatively firmly pushed towards the main body **10**, the pins **182**, **184**, **186** are then heat staked and the chassis **102** is therefore after this held very firmly in position in the main body and is unable to move, thereby assisting in providing great accuracy for the dose counter **36**. Next, as shown in FIG. **8D**, the

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dose counter chamber cover **120** may be fitted over the dose counter chamber **66** and may be secured in place such as by welding, with the priming dot **216** being displayed through the window.

The user can, when readying the inhaler **12** for first use, prime the inhaler by depressing the canister **20** three times which will bring the first number **114** on the tape into display through the window **118** in place of the priming dot **216**, the number **114** shown in FIG. **8D** being “200”, thereby indicating that 200 doses are remaining to be dispensed from the canister **20** and inhaler **12**.

As shown in FIG. **8D**, and in FIG. **5**, an open drain hole **194** is provided at the bottom of the dose counter chamber **66** by a substantially semi-circular cut-out or recess formation **196** in a lower surface **198** of the main body **10** of the inhaler. Accordingly, if the user (not shown) should decide to wash the main body **10** of the inhaler, for example after encountering an unhygienic situation or simply as a matter of choice, the drain hole **194** allows initial draining of water from inside the dose counter chamber **66** and also thereafter evaporation of water or any aqueous matter in the dose counter chamber **66** so that the window **118** does not mist up undesirably.

FIG. **14** shows a computer system **230** for designing the dose counter **36** and in particular for calculating distributions representative of average positions and standard deviations in a production series of inhalers of the start, reset, fire, count and end positions of the actuator lower side edge **98** relative to the datum plane **220** (FIG. **9**) and therefore of the actuator pawl **80** generally relative to the ratchet wheel **94**, chassis **102** and, when the inhaler **12** is fully assembled, the main body **10** of the inhaler **12**. The computer system **230** includes a data store **232**, a CPU **234**, an input device **236** (such as a keyboard or communication port) and an output device **238** (such as a communications port, display screen and/or printer). A user may enter data via the input device **236** which may be used by the CPU **234** in a mathematical calculation to predict count failure rates when the various dose counters are to be built in a series with dose counter positions set with given averages and standard deviations and taking into account any momentum/inertia effects and metering valve user-back-pressure reduction effect which will occur upon canister firing of a given type of canister. The computer system **230** is thus mathematically used to design the distributions. For the inhaler **12** described herein with the dose counter **36** and canister **20**, the distributions are designed as shown in FIG. **11**. The x axis shows distance of the lower side surface **98** of the actuator **80** above the datum plane **220** and the y axis is representative of the distribution. Thus, curve **240** shows that the start configuration has an average 1.33 mm above the datum plane **200** (standard deviation is 0.1 mm), curve **242** shows that the reset configuration has an average of 0.64 mm above the datum plane **220** (standard deviation is 0.082 mm), curve **244** shows the fire configuration has an average 0.47 mm below the datum plane **220** (standard deviation is 0.141 mm), curve **246** shows the count configuration has an average 0.95 mm below the datum plane **220** (standard deviation is 0.080 mm), and curve **248** shows the end configuration has an average of 1.65 mm below the datum plane **220** (standard deviation is 0.144 mm).

FIGS. **15** to **20** show a version of the inhaler modified in accordance with the present invention. In these drawings, the same reference numerals have been used to those in the earlier drawings to denote the equivalent components. The inhaler **12** is the same as that in FIGS. **1** to **14** apart from the following modifications.

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First, it can be seen that there is a modification in that the drive teeth **92** of the ratchet wheel **94** have a different profile to that in FIGS. **1** to **14**. There are also only nine ratchet teeth **94** in this embodiment instead of eleven.

Additionally, as shown in FIGS. **18C** and **19C**, the control elements **128**, **130** on the forks **124**, **126** of the second shaft **108** have a tapered profile which is different to the profile of the control elements **128**, **130** shown in FIG. **6F**. Either profile can be used in the embodiment of FIGS. **15** to **20** however.

Furthermore, as shown in FIG. **15**, the tape stock bobbin **110** has an inwardly facing generally cylindrical engagement surface **300** with a wavelike form extending partially therealong. The engagement surface **300** has a cross-section **301** perpendicular to the longitudinal length of the stock bobbin **110** which is constant therealong. This cross-section **301** can be seen in FIG. **16** and consists of a series of ten regularly spaced concavities **302** and ten convex wall portions **304**. The convex wall portions **304** are equi-spaced between the concavities **302**. Each concavity **302** has a radius of 0.2 mm. Each convex wall portion **304** also has a radius of 0.2 mm. Finally, the cross section **301** also includes flat wall portions **306** between all of the radiused wall portions of the concavities **302** and convex wall portions **304**. The geometry of the cross-section **301** is therefore defined by the radii of the concavities **302** and convex wall portions **304**, the flat wall portions **306** and the fact that there are ten concavities **302** and convex wall portions **304**.

The minor diameter of the engagement surface **300**, i.e. between the tips of opposite convex wall portions **304**, is 2.46 mm. The major diameter of the engagement surface **300**, i.e. between the outermost portions of the concavities **302**, is 2.70 mm. The undeformed tip to tip maximum diameter of the forks **124**, **126** of the split pin (the second shaft) **108**, i.e. in the region of the maximum radio extent of the control elements **128**, **130**, is 3.1 millimeters and it will therefore be appreciated that the forks **124**, **126** are resiliently compressed once the stock bobbin **110** has been assembled onto the split pin **108** in all rotational configurations of the stock bobbin **110** relative to the split pin **108**. The minimum gap between the forks **124**, **126** in the plane of the cross sections of FIGS. **18C** and **19C** is 1 mm when the split pin **108** is in the undeformed, pre-inserted state. When the split pin **108** is at maximum compression, as shown in FIGS. **18A** to **18C** when the control elements **128**, **130** are shown to be engaged on top of the convex wall portions **304**, the gap **308** between the tips **310**, **312** of the forks **124**, **126** is 0.36 mm. On the other hand, when the split pin **108** is at minimum compression (once inserted into the stock bobbin) as shown in FIGS. **19A** to **19C**, when the control elements **128**, **130** rest in the concavities **302**, the gap between the tips **310**, **312** of the forks **124**, **126** is 0.6 mm. The control elements **128**, **130** are outwardly radiused with a radius also of 0.2 mm such that they can just rest on the concavities **302** with full surface contact (at least at an axial location on the split pin where the tapered control elements are at their maximum radial extent), without rattling in, locking onto or failing to fit in the concavities **302**. The radii of the control elements **128**, **130** is therefore preferably substantially the same as the radii of the concavities **302**.

It will be appreciated that whereas FIGS. **18B** and **19B** are end views along the coaxial axis of the stock bobbin **110** and split pin **108**, FIGS. **18A** and **19A** are cross-sections. FIG. **19A** is a section on the plane A-A' in FIG. **19C** and FIG. **18A** is a section at the same plane, but of course with the stock bobbin **110** rotated relative to the split pin **108**.

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As the inhaler 12 is used and the ratchet wheel 94 rotates in order to count used doses, the stock bobbin rotates incrementally through rotational positions in which rotation is resisted, i.e. due to increasing compression of the split pin 108 at such rotational positions, and rotational positions in which rotation is promoted, i.e. due to decreasing compression of the split pin 108 at such rotational positions and this may involve a click forward of the stock bobbin 110 to the next position equivalent to that in FIGS. 19A to 19C in which the control elements 128, 130 of the split pin art located in the concavities 302. This functionality firstly allows the stock bobbin to unwind during use as required, but also prevents the tape 112 from loosening during transit if the inhaler 12 is dropped, such as onto a hard surface. This is highly advantageous, since the tape 11 is prevented from moving to a position in which it will give an incorrect reading regarding the number of doses in the canister.

During compression and expansion of the forks in the radial direction between the two configurations shown in FIGS. 18C and 19C, the forks 124, 126 rotate about a point 316 on the split pin where the forks 124, 126 come together. This rotational action means that there is a camming action between the forks 124, 126 and the engagement surface 300 without significant friction but, nevertheless, the resilient forces provided by the regulator formed by the engagement surface 300 and forks 124, 126 are able to regulate unwinding of the tape such that it does not easily occur during transit or if the inhaler 12 is dropped. It has been found during testing that a force of 0.3 to 0.4 N needs to be applied to the tape 112 to overcome the regulator at the stock bobbin 110. 0.32 N is achieved with the control elements 128 having the profile shown in FIG. 19C and 0.38 N is achieved with the profile of the control elements 128 altered to be as shown as described with reference to FIG. 6F. These forces are substantially higher than the 0.1 N force mentioned above and undesirable movement of the tape is substantially avoided even if the inhaler is dropped onto a hard surface. The modified arrangement of FIGS. 15 to 20 does not provide this force "constantly" such that there is overall not an undesirably high friction of the tape 112 as it passes over the other components of the dose counter because, due to the incremental nature of the resilient forces at the regulator, the tape 112 can incrementally relax as it slides over the stationary chassis components.

Instead of having ten concavities 302 and convex wall portions 304, other numbers may be used, such as 8 or 12. However, it is preferred to have an even number, especially since two control elements 128, 130 are provided, so that all of the control elements 128, 130 will expand and contract simultaneously. However, other arrangements are envisaged with 3 or more forks and the number of concavities/convex wall portions may be maintained as an integer divisible by the number of forks to maintain a system with simultaneous expansion/contraction. For example, the use of 9, 12 or 15 concavities/convex wall portions with 3 forks is envisaged.

Instead of having the engagement surface 300 on the inside of the stock bobbin 110, it could be placed on the outside of the stock bobbin 110 so as to be engaged by flexible external legs/pawls or similar.

It will be noted that the regulator provided by the engagement surface 300 and forks 124, 126 does not only allow rotation of the stock bobbin in one direction as is the case with the ratchet wheel 94. Rotation in both directions is possible, i.e. forwards and backwards. This means that during assembly, the stock bobbin 110 can be wound backwards during or after fitting the bobbin 100, shaft 106 and tape 112 onto the carriage 102, if desired.

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The stock bobbin 110 and the carriage 102 including the split pin 108 are both moulded of polypropylene material.

It will be seen from FIG. 16 that the cross-sectional shape 301 is not symmetrical within the hexagonal socket 204. This has enabled the hexagonal socket 204 to be maintained at a useful size while still allowing the desired size and geometry of the cross section 301 to fit without interfering with the hexagonal shape of the hexagonal socket 204 and also permits moulding to work during manufacture.

As shown in FIG. 17, the stock bobbin 110 has a series of four circumferential ribs 330 inside it and a spaced therealong. These hold the stock bobbin 110 on the correct side of the mould tool during moulding.

FIGS. 21 and 22 show a preferred embodiment in accordance with the invention of an inhaler 510 for dispensing a dry-powdered medicament in metered doses for patient inhalation. The inhaler 510 is as disclosed in FIGS. 1 to 16 or EP-A-1330280, the contents of which are hereby fully incorporated herein by reference, but with the stock bobbin 110 and second shaft 108 of the dose counter 516 modified so as to be as in FIGS. 15 to 20 hereof. Thus, the dry powder inhaler 510 generally includes a housing 518, and an assembly 512 received in the housing (see FIG. 21). The housing 518 includes a case 520 having an open end 522 and a mouthpiece 524 (FIG. 25) for patient inhalation, a cap 526 secured to and closing the open end 522 of the case 520, and a cover 528 pivotally mounted to the case 520 for covering the mouthpiece 524. As shown in FIG. 22, the inhaler 510 also includes an actuation spring 569, first yoke 566 with opening 572, bellows 540 with crown 574, a reservoir 514, second yoke 568 with hopper 542 and dose counter 516 mounted thereto, and case 520 has transparent window 5130 thereon for viewing dose counter tape indicia 5128. The dose metering system also includes two cams 570 mounted on the mouthpiece cover 528 and movable with the cover 528 between open and closed positions. The cams 570 each include an opening 580 for allowing outwardly extending hinges 582 of the case 520 to pass therethrough and be received in first recesses 584 of the cover 528. The cams 570 also include bosses 586 extending outwardly and received in second recesses 588 of the cover 528, such that the cover 528 pivots about the hinges 582 and the cams 570 move with the cover 528 about the hinges 582. As described in EP-A-1330280, cams 570 act upon cam followers 578 to move second yoke 568 up and down and thereby operate dose counter by engagement of pawl 5138 on the second yoke 568 with teeth 5136. Remaining components of the inhaler are provided as, and operate as described, in EP-A-1330280.

The dose counting system 516 therefore includes a ribbon or tape 5128 (FIGS. 23 & 24), having successive numbers or other suitable indicia printed thereon, in alignment with a transparent window 5130 provided in the housing 18 (see FIG. 22). The dose counting system 516 includes the rotatable stock bobbin 110 (as described above), an indexing spool 5134 rotatable in a single direction, and the ribbon 5128 rolled and received on the bobbin 110 and having a first end 5127 secured to the spool 5134, wherein the ribbon 5128 unrolls from the bobbin 110 so that the indicia are successively displayed as the spool 5134 is rotated or advanced. In FIGS. 23 and 24 the wavelike engagement surface 300 of the bobbin 110 is not shown for the purposes of clarity.

The spool 134 is arranged to rotate upon movement of the yokes 566, 568 to effect delivery of a dose of medicament from reservoir 514, such that the number on the ribbon 5128 is advanced to indicate that another dose has been dispensed by the inhaler 510. The ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase or



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decrease upon rotation of the spool 5134. For example, the ribbon 5128 can be arranged such that the numbers, or other suitable indicia, decrease upon rotation of the spool 5134 to indicate the number of doses remaining in the inhaler 510. Alternatively, the ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase upon rotation of the spool 5134 to indicate the number of doses dispensed by the inhaler 10.

The indexing spool 5134 includes radially extending teeth 5136, which are engaged by pawl 5138 extending from a cam follower 578 of the second yoke 568 upon movement of the yoke to rotate, or advance, the indexing spool 5134. More particularly, the pawl 5138 is shaped and arranged such that it engages the teeth 5136 and advances the indexing spool 5134 only upon the mouthpiece cover 528 being closed and the yokes 566, 568 moved back towards the cap 526 of the housing 518.

The dose counting system 516 also includes a chassis 5140 that secures the dose counting system to the hopper 542 and includes shafts 108, 5144 for receiving the bobbin 110 and the indexing spool 5134. As described above with reference to FIGS. 1 to 20, the bobbin shaft 108 is forked and includes radially nubs 5146 for creating a resilient resistance to rotation of the bobbin 110 on the shaft 108 by engaging with the wavelike engagement surface 300 inside the bobbin 110. A clutch spring 5148 is received on the end of the indexing spool 5134 and locked to the chassis 5140 to allow rotation of the spool 5134 in only a single direction.

Various modifications may be made to the embodiment shown without departing from the scope of the invention as defined by the accompanying claims as interpreted under patent law.

What is claimed is:

1. A dose counter for a metered dose inhaler having a body arranged to retain a medicament canister of predetermined configuration for movement of the medicament canister relative thereto, the medicament canister containing an active drug; the dose counter comprising:

a ratchet wheel having a plurality of circumferentially spaced teeth,

an actuator comprising an actuator pawl arranged to engage with a first tooth of the ratchet wheel, wherein the actuator can be driven in response to canister motion to drive the ratchet wheel to rotate,

a count pawl arranged to engage with a second tooth of the ratchet wheel, wherein as the ratchet wheel is driven by the actuator to rotate, the count pawl rides along a forward surface of the second tooth and resiliently jumps over the second tooth, and

a dosage indicator associated with the count pawl, wherein the actuator is arranged to define a first reset position in which the actuator pawl is brought into engagement with the first tooth,

wherein the actuator is further arranged such that, during a canister fire sequence, when the actuator is in a second position, which is after the first reset position and at a canister fire configuration, the medicament canister fires medicament before the dose counter reaches a count configuration, and when the actuator is in a third position after the second position, the count pawl resiliently jumps over the second tooth and the dose counter reaches the count configuration, whereby the dosage indicator has indicated a count,

wherein, in the canister fire configuration, the actuator pawl is below a datum plane which passes through a shoulder of a valve stem block configured to receive the medicament canister.

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2. A dose counter as claimed in claim 1 in which the actuator is displaced less than 1 mm relative to the body between its locations in the canister fire and count configurations.

3. A dose counter as claimed in claim 1 wherein the dosage indicator includes a tape with incremental dose indicia located thereon, the tape being positioned on a tape stock bobbin and arranged to unwind therefrom.

4. The dose counter as claimed in claim 3, wherein the incremental dose indicia on the tape is in the form of even numbers and the body includes a dose marker that points to a location either at one of the even numbers or between two adjacent even numbers.

5. A dose counter as claimed in claim 1 in which the actuator and ratchet wheel are arranged to provide a start configuration at which the actuator is spaced from the ratchet wheel, and an end configuration at which the actuator disengages from the ratchet wheel during the canister fire sequence.

6. A dose counter as claimed in claim 5 in which:

(a) the actuator is arranged to be located about 1.5 to 2.0 mm from its location in the fire configuration when in the start configuration;

(b) the actuator is arranged to be located about 1.0 to 1.2 mm from its location in the fire configuration when in the reset configuration; or

(c) the actuator is arranged to be located about 1.1 to 1.3 mm from its location in the fire configuration when in the end configuration.

7. A dose counter as claimed in claim 5 in which the body includes a formation for forcing the actuator to disengage from the ratchet wheel when the actuator is moved past the end configuration.

8. A dose counter as claimed in claim 5 in which:

(a) the actuator is arranged to be located about 1.5 to 2.0 mm from its location in the fire configuration when in the start configuration;

(b) the actuator is arranged to be located about 1.0 to 1.2 mm from its location in the fire configuration when in the reset configuration; and

(c) the actuator is arranged to be located about 1.1 to 1.3 mm from its location in the fire configuration when in the end configuration.

9. A dose counter as claimed in claim 1, wherein the count pawl and the ratchet wheel are arranged to permit one way incremental relative motion therebetween.

10. A dose counter as claimed in claim 9 in which the actuator and ratchet wheel are arranged to provide a start configuration at which the actuator is spaced from the ratchet wheel, and an end configuration at which the actuator disengages from the ratchet wheel during the canister fire sequence and in which the count pawl is substantially fixedly mounted on the body and in which the count pawl is arranged to be capable of repeatedly engaging the teeth of the ratchet wheel in anti-back drive interlock configurations as the dose counter is operated, the count pawl being positioned so that the ratchet wheel is halfway, or substantially halfway, moved from one anti-back interlock configuration to the next when the actuator and ratchet wheel are in the end configuration thereof.

11. An inhaler comprising the body arranged to retain the medicament canister of predetermined configuration and the dose counter as claimed in claim 1.

12. An inhaler as claimed in claim 11 in which the body includes a canister-receiving portion and a separate counter chamber; the body, ratchet wheel and actuator being located inside the counter chamber, the body of the inhaler having

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wall surfaces separating the canister-receiving portion and the counter chamber, the wall surfaces being provided with a communication aperture, an actuation member extending through the communication aperture to transmit canister motion to the actuator.

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**13.** The dose counter of claim **1**, wherein the shoulder is a bottom surface within the valve stem block and the datum plane is perpendicular to a direction of the movement of the medicament canister.

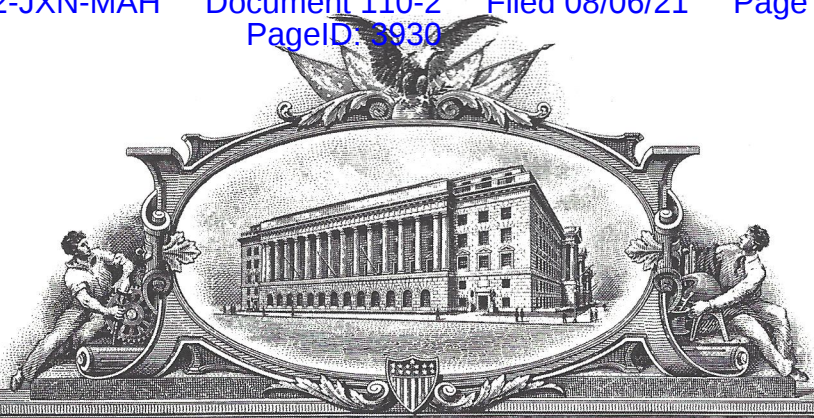
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## **EXHIBIT 4**

U 8079874

**THE UNITED STATES OF AMERICA****TO ALL TO WHOM THESE PRESENTS SHALL COME:****UNITED STATES DEPARTMENT OF COMMERCE****United States Patent and Trademark Office**

February 26, 2021

**THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM  
THE RECORDS OF THIS OFFICE OF:****U.S. PATENT: 10,561,808****ISSUE DATE: February 18, 2020****By Authority of the****Under Secretary of Commerce for Intellectual Property  
and Director of the United States Patent and Trademark Office****P. R. GRANT  
Certifying Officer**

(12) **United States Patent**  
**Walsh et al.**

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 (45) **Date of Patent:** **Feb. 18, 2020**

(54) **DOSE COUNTER FOR INHALER HAVING AN ANTI-REVERSE ROTATION ACTUATOR**

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(65) **Prior Publication Data**  
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*G06M 1/24* (2006.01)  
*A61M 11/00* (2006.01)

(52) **U.S. Cl.**  
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(58) **Field of Classification Search**  
 CPC ..... *A61M 15/0078*; *A61M 15/0025*; *A61M 15/0026*; *A61M 15/007*; *A61M 15/0071*; (Continued)

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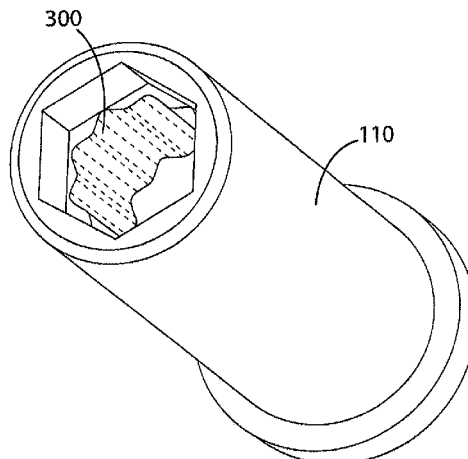
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*Primary Examiner* — Daniel A Hess  
 (74) *Attorney, Agent, or Firm* — Morgan, Lewis & Bockius LLP

(57) **ABSTRACT**

A dose counter for an inhaler includes a counter display arranged to indicate dosage information, and a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input. A regulator is provided which is arranged (Continued)





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to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

29 Claims, 17 Drawing Sheets

Related U.S. Application Data

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- (60) Provisional application No. 61/345,763, filed on May 18, 2010, provisional application No. 61/417,659, filed on Nov. 29, 2010.
- (52) **U.S. Cl.**  
CPC ..... *A61M 15/009* (2013.01); *A61M 15/0025* (2014.02); *A61M 15/0026* (2014.02); *A61M 15/0065* (2013.01); *A61M 15/0071* (2014.02); *G06M 1/246* (2013.01); *A61M 2202/064* (2013.01); *A61M 2205/6063* (2013.01); *A61M 2207/00* (2013.01); *A61M 2207/10* (2013.01); *Y10T 29/49* (2015.01); *Y10T 29/49764* (2015.01); *Y10T 29/49826* (2015.01)
- (58) **Field of Classification Search**  
CPC ..... *A61M 11/00*; *A61M 15/0065*; *A61M 15/009*; *G06M 1/246*  
USPC ..... 235/8  
See application file for complete search history.

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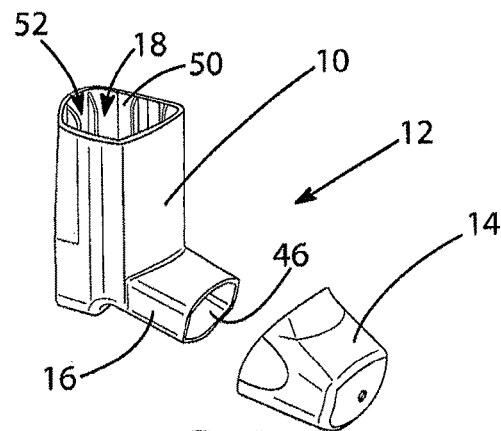


FIG. 1

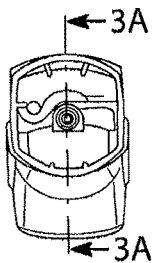


FIG. 2

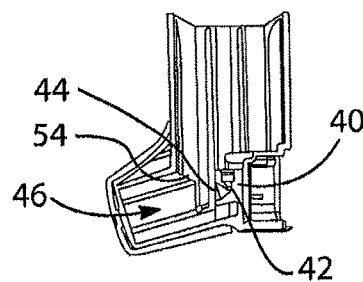


FIG. 3A

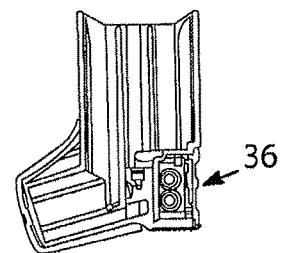


FIG. 3B

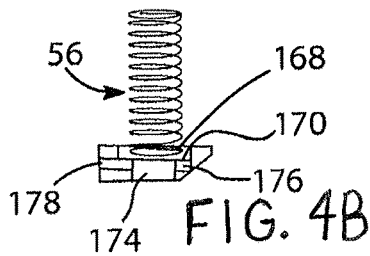


FIG. 4B

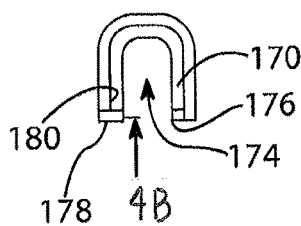


FIG. 4C

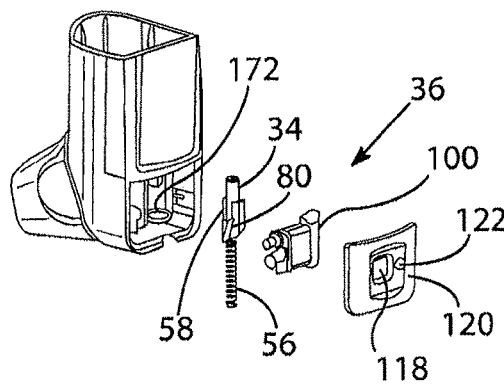


FIG. 4A

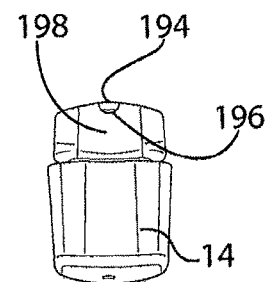


FIG. 5

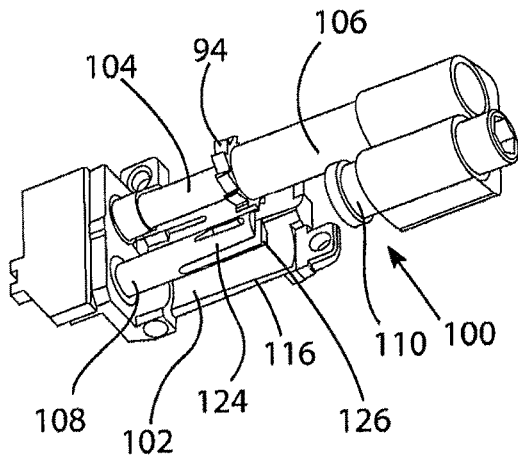


FIG. 6A

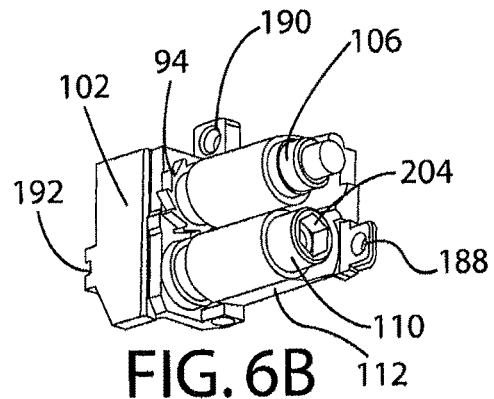


FIG. 6B

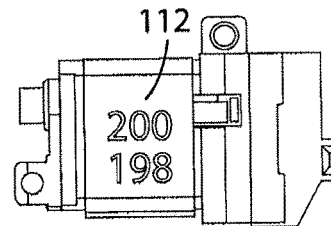


FIG. 6C

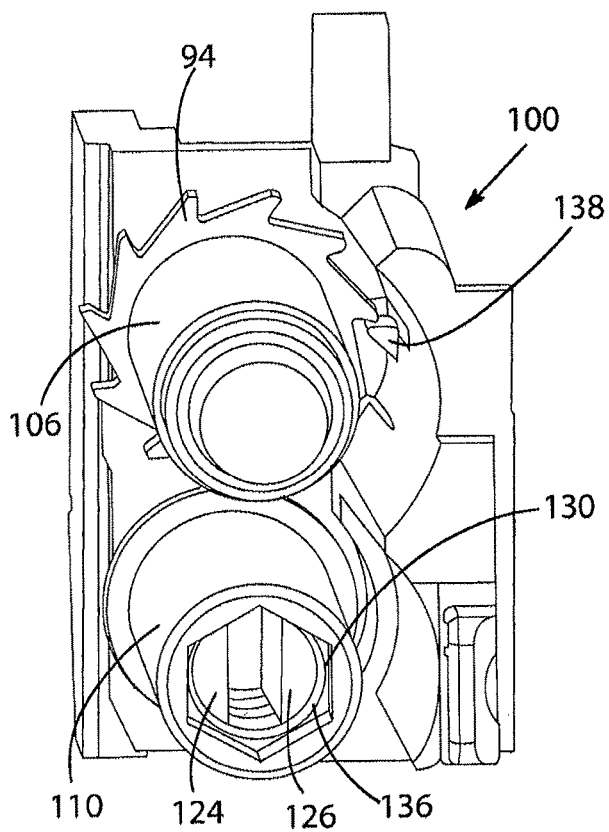


FIG. 6D

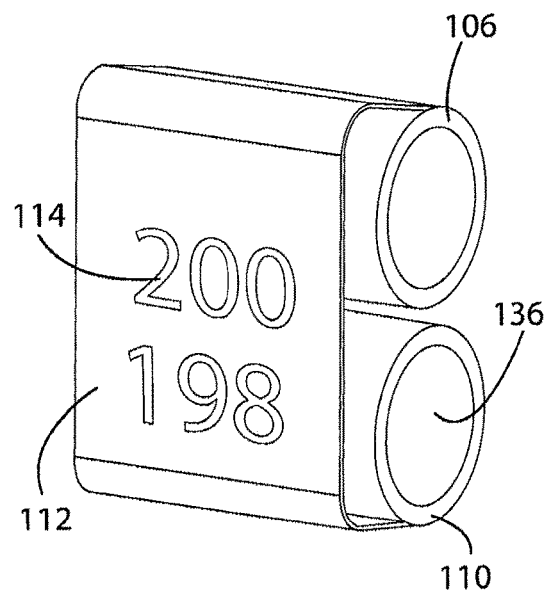


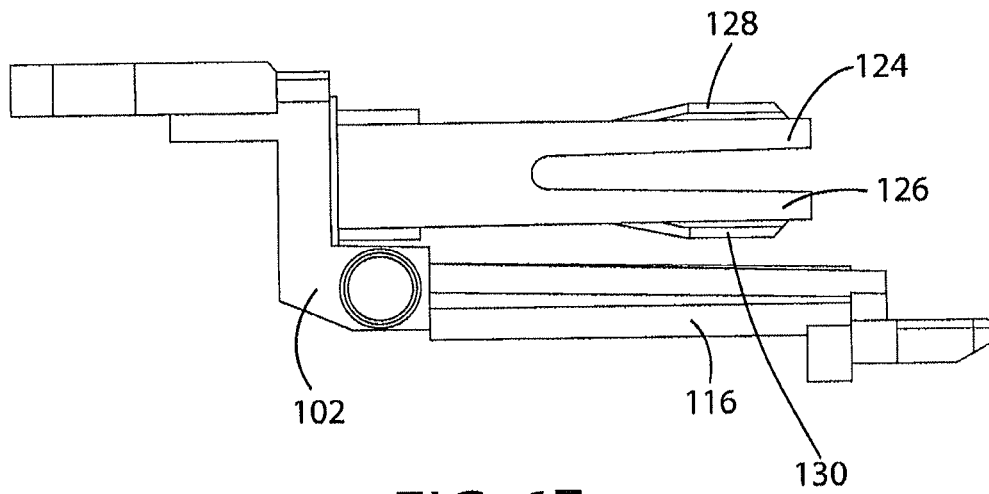
FIG. 6E

**U.S. Patent**

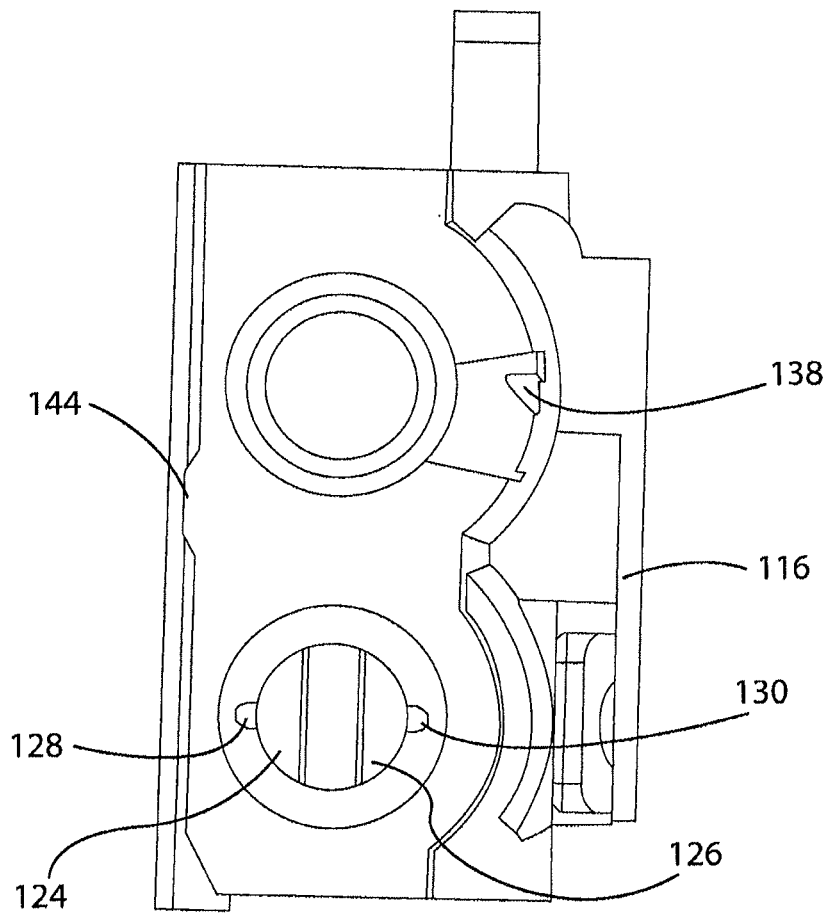
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**FIG. 6F**



**FIG. 6G**

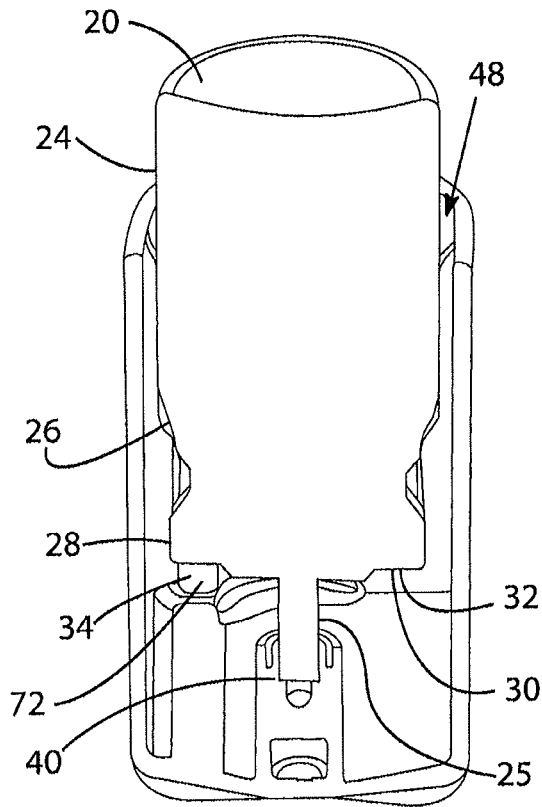


FIG. 7A

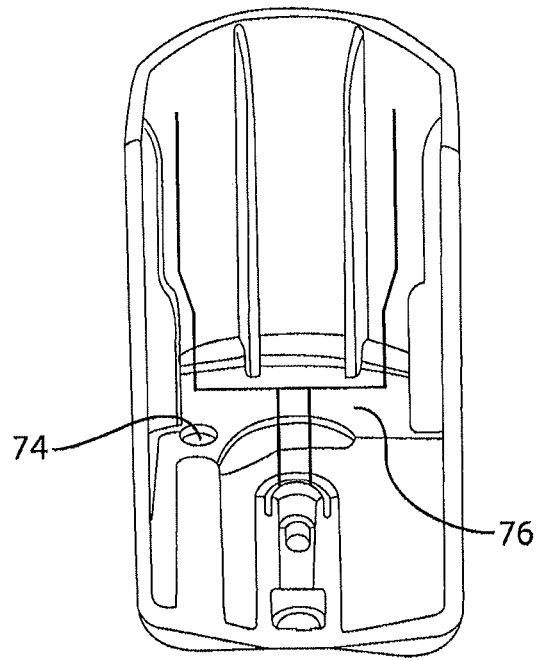


FIG. 7B

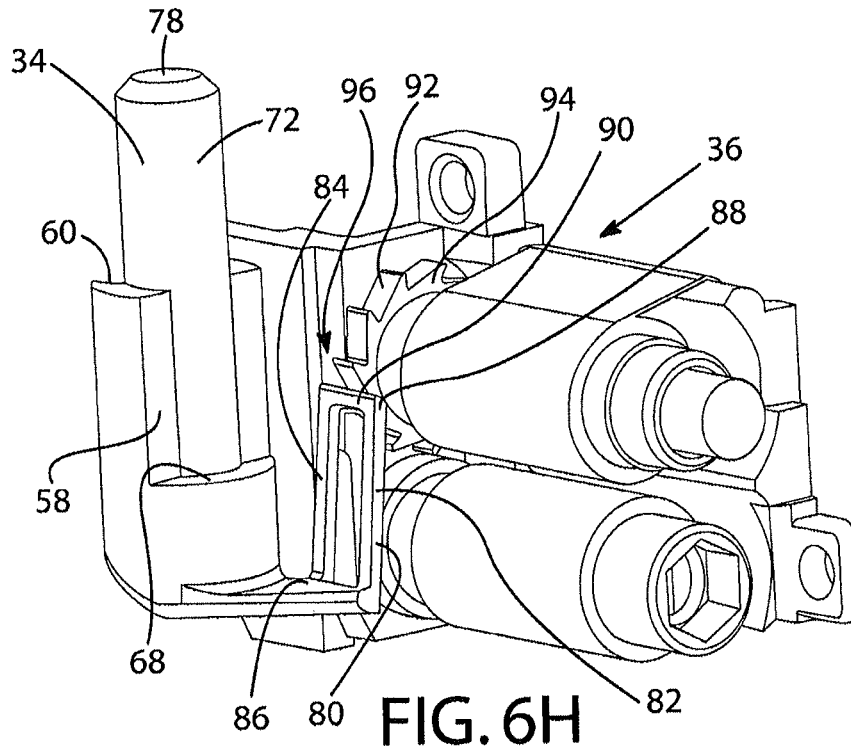


FIG. 6H

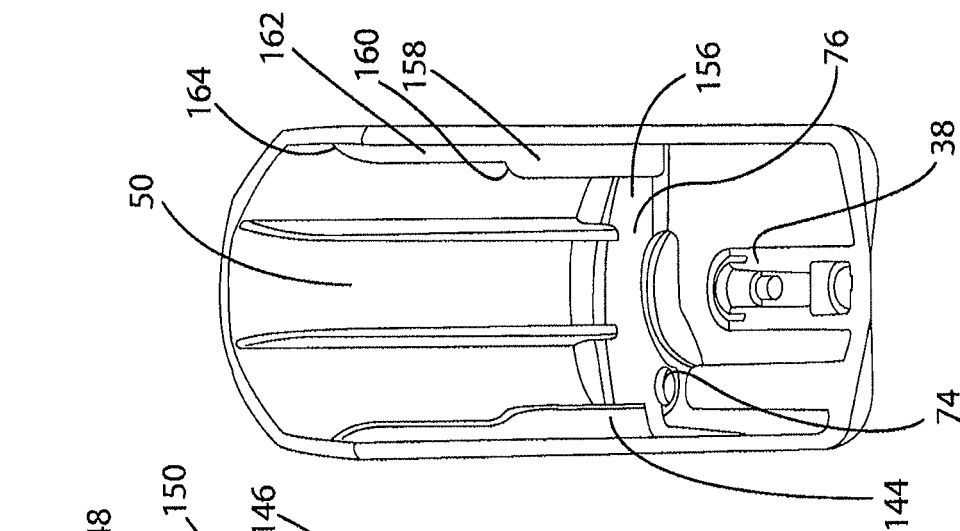


FIG. 7C

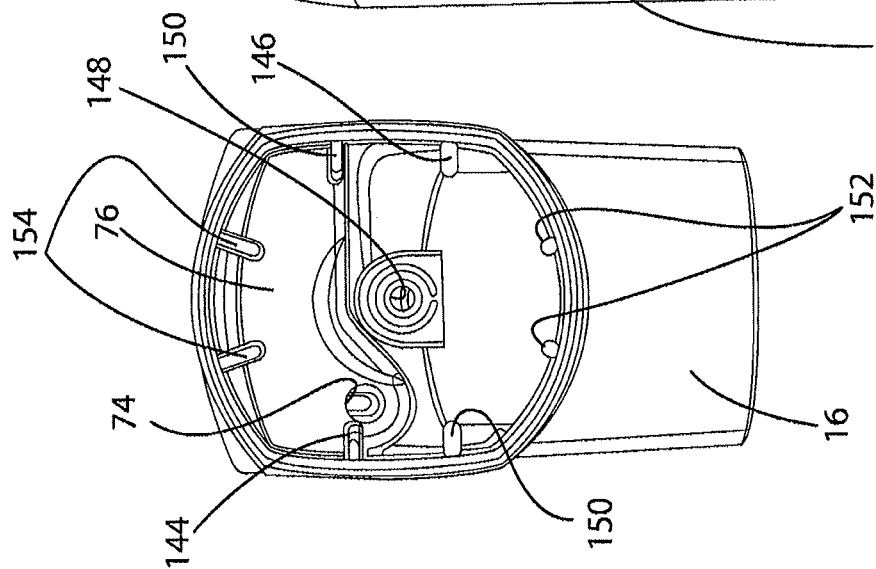


FIG. 7D

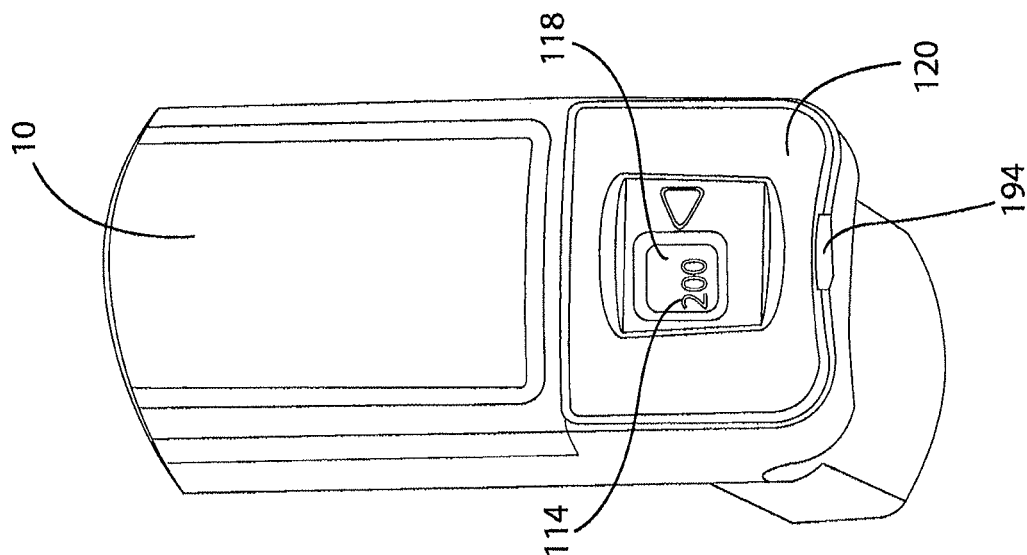


FIG. 8D



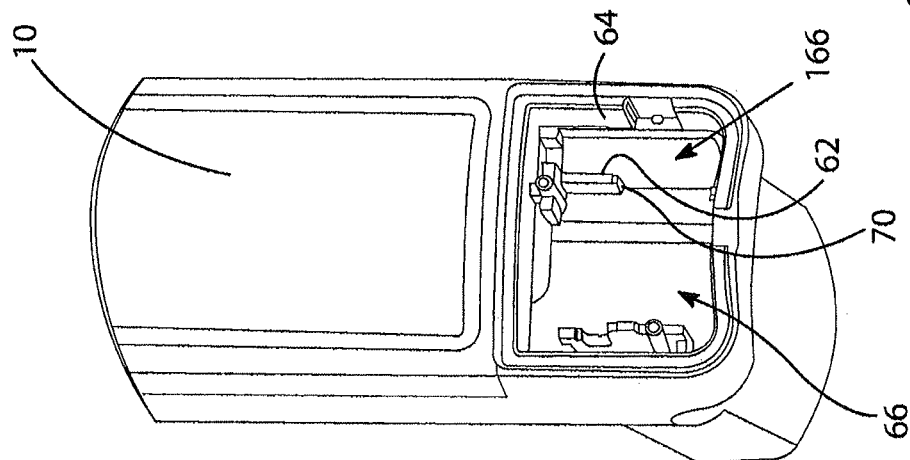


FIG. 8A

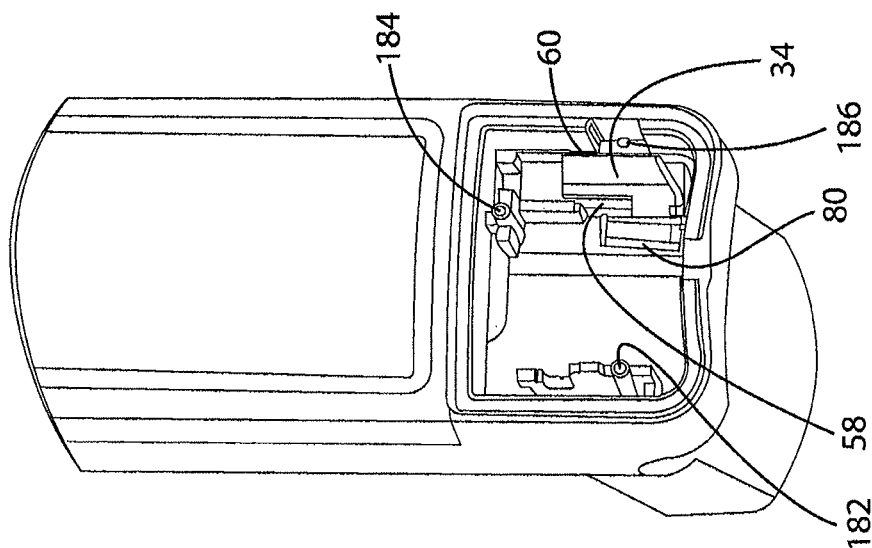


FIG. 8B

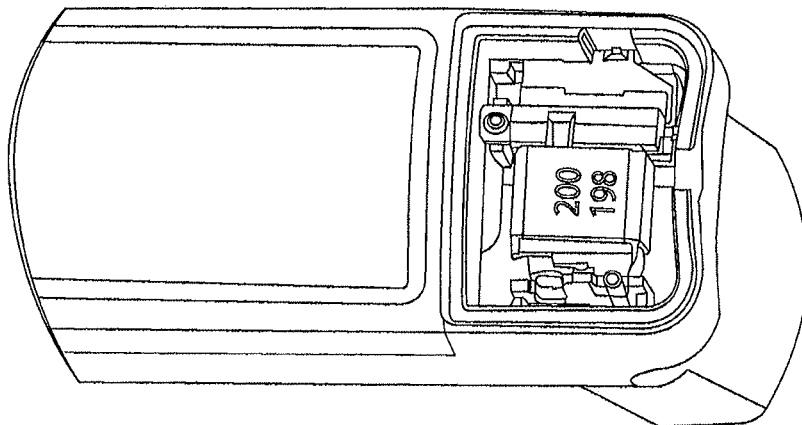


FIG. 8C

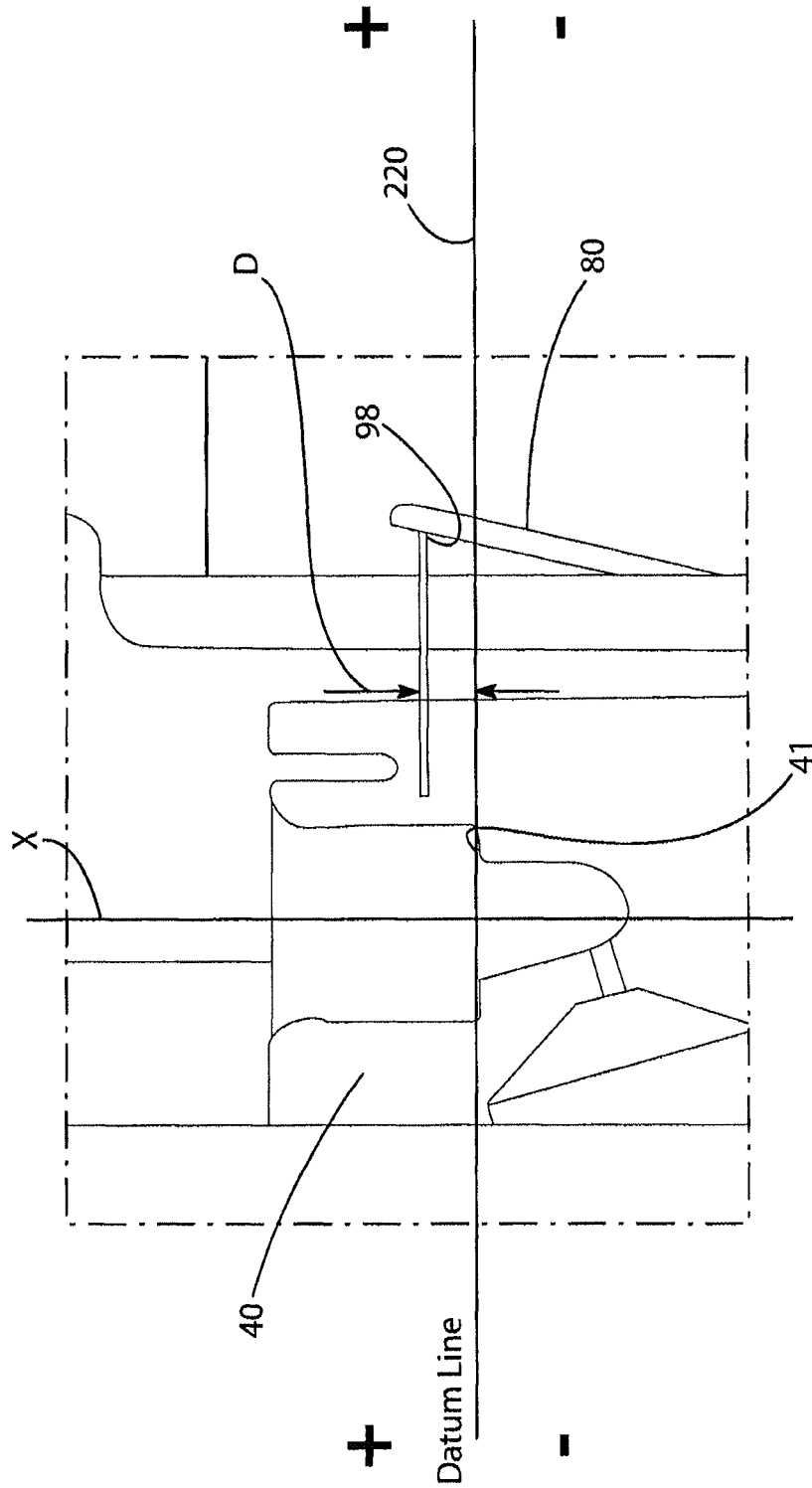


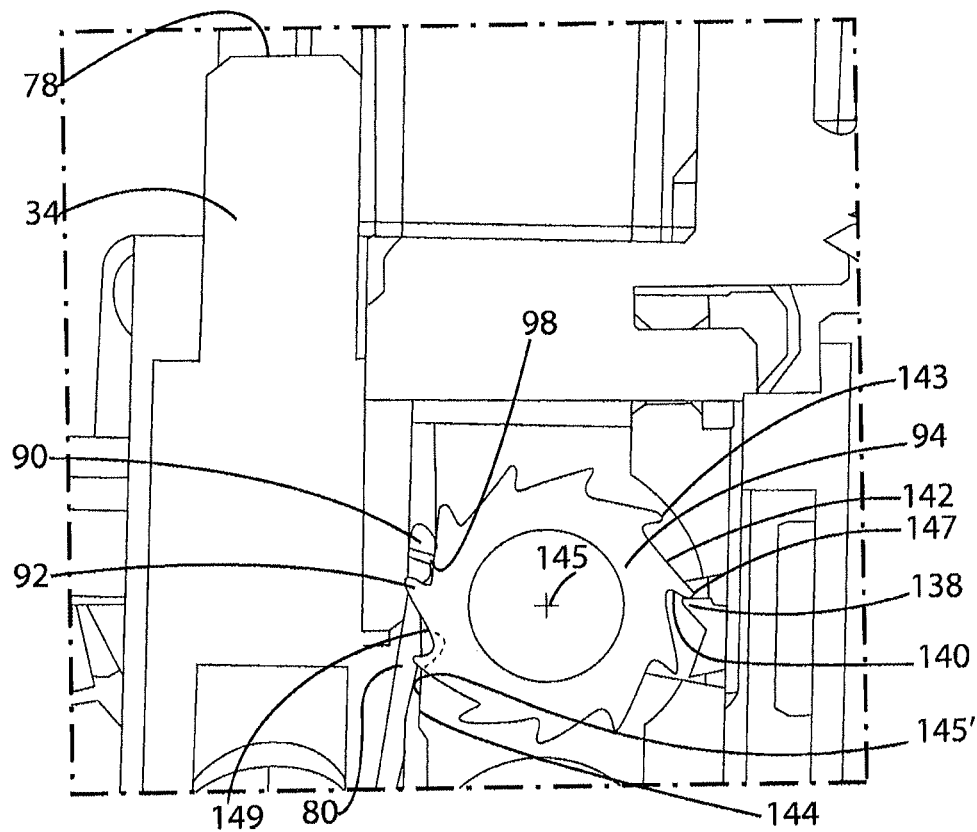
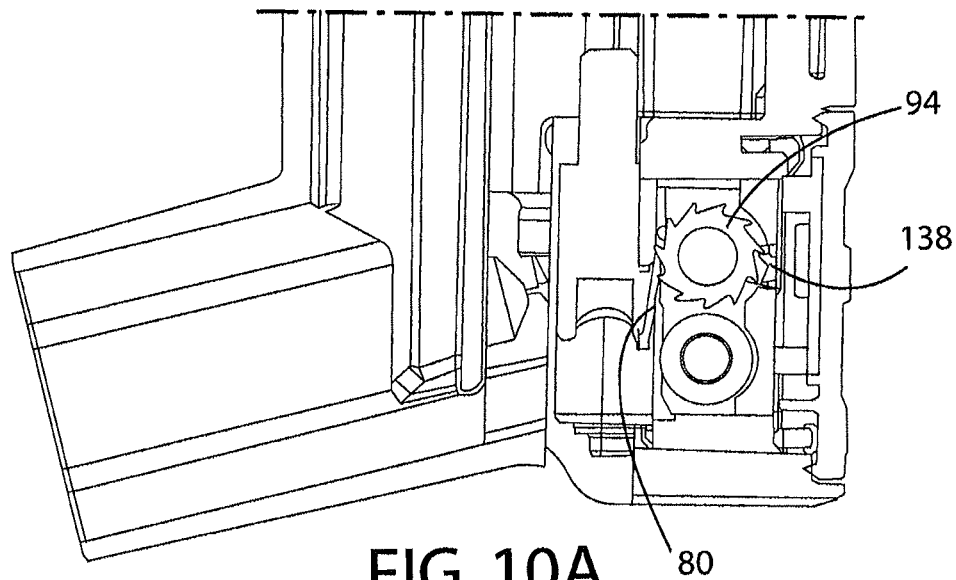
FIG. 9

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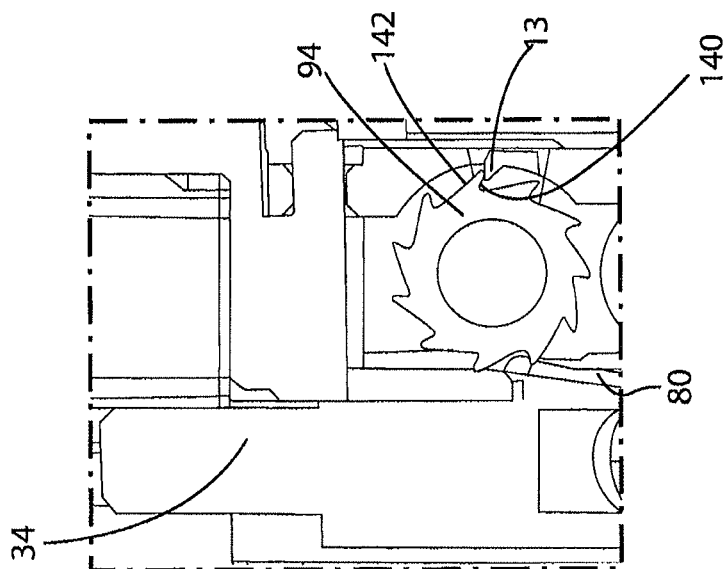


FIG. 10E

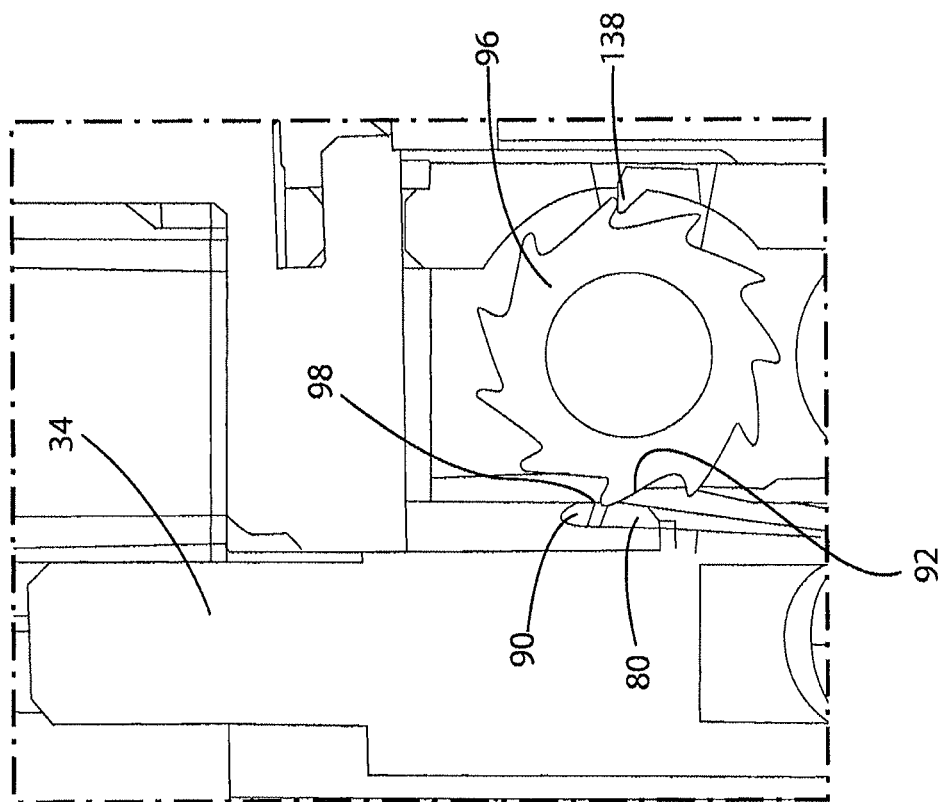


FIG. 10C

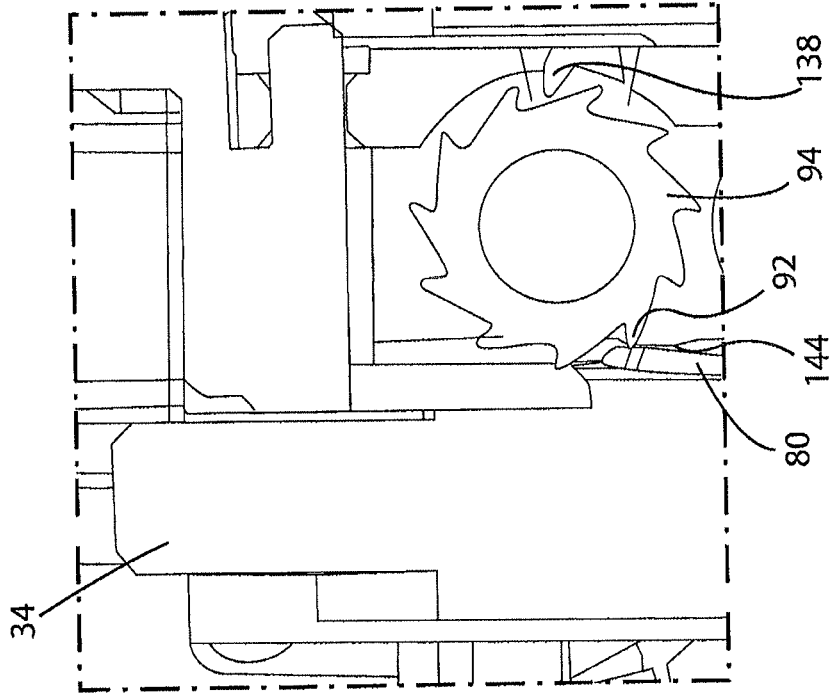


FIG. 10F

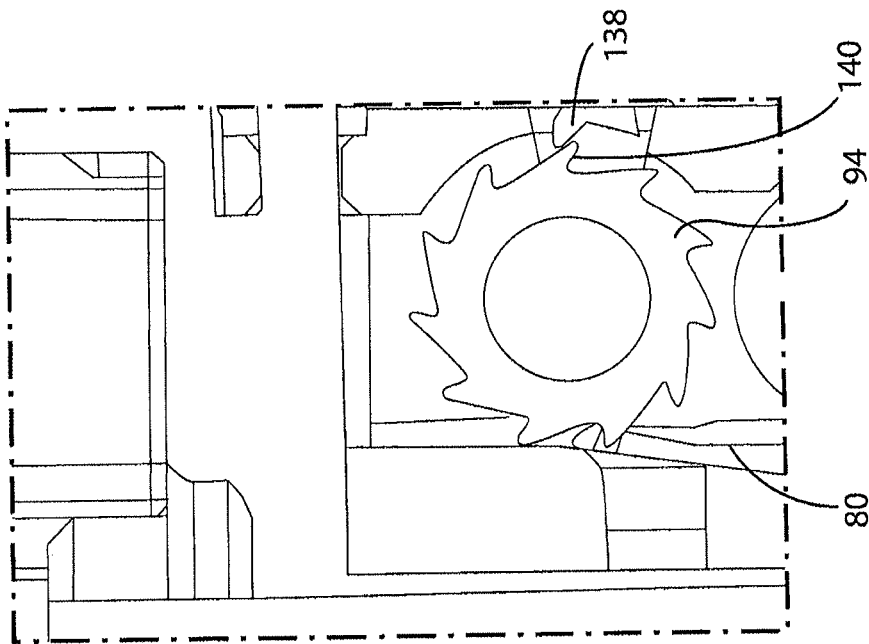


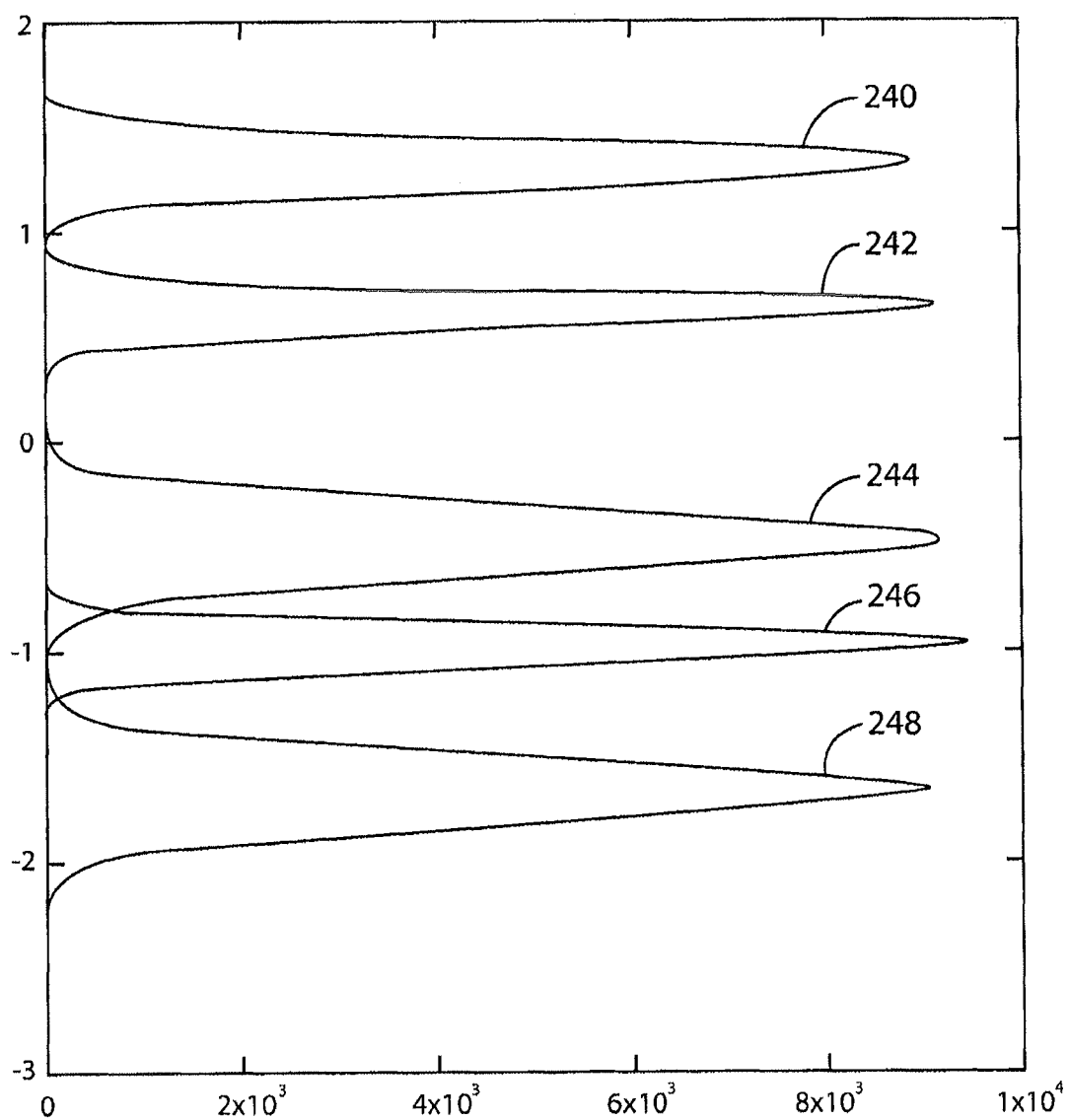
FIG. 10D

**U.S. Patent**

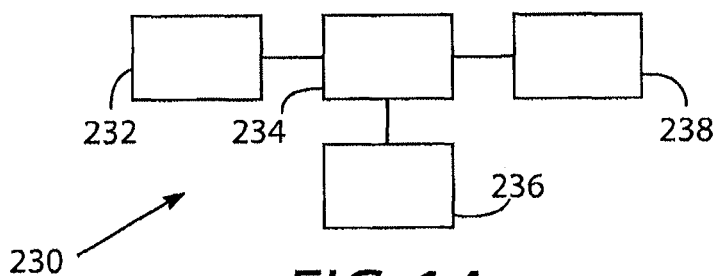
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**FIG. 11**



**FIG. 14**



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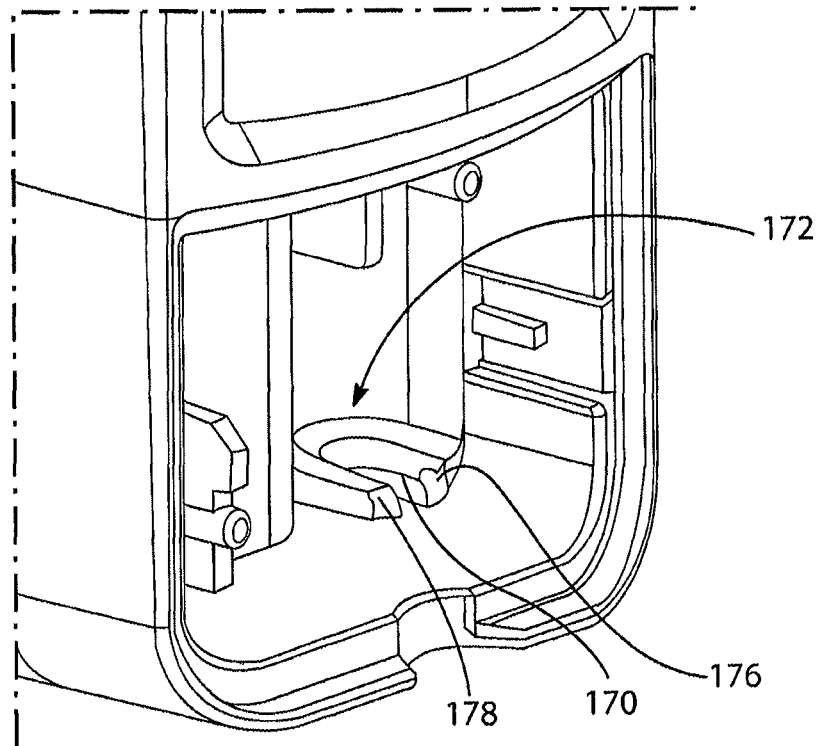


FIG. 12

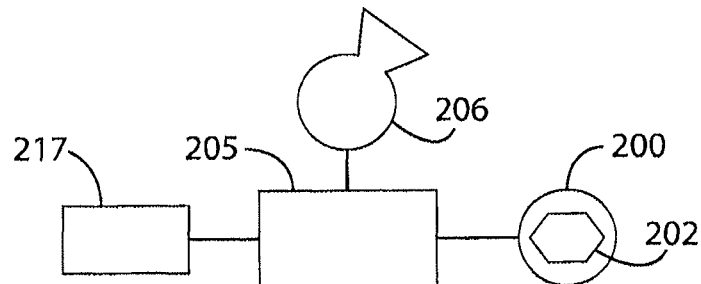
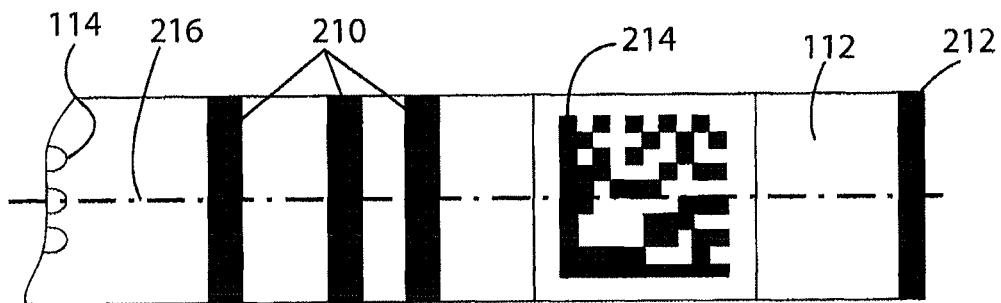


FIG. 13

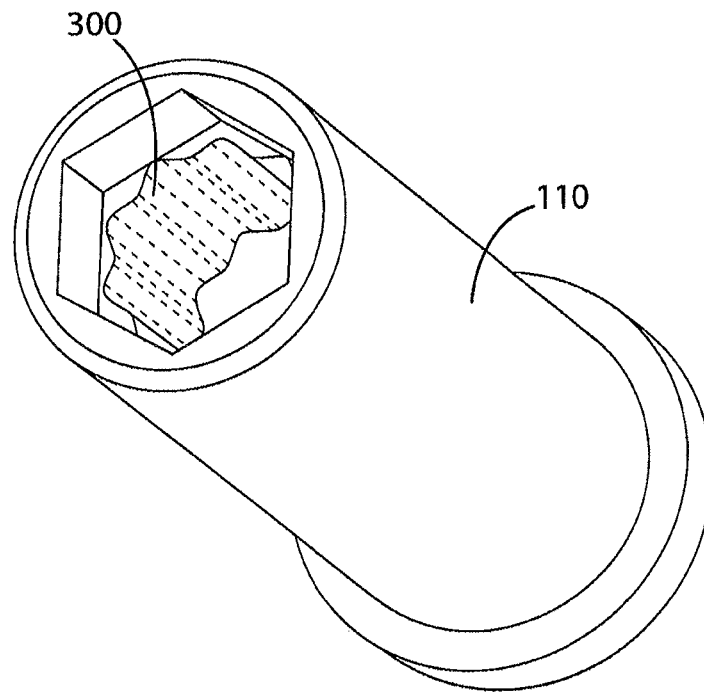


FIG. 15

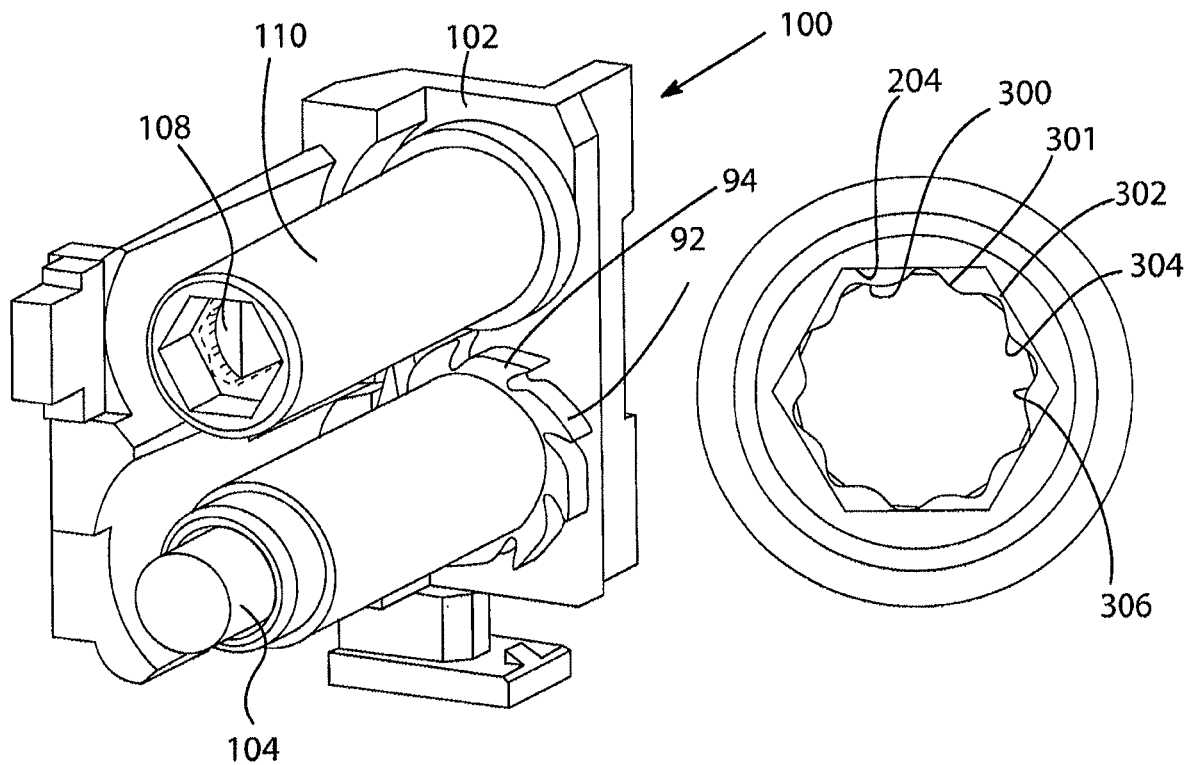


FIG. 20

FIG. 16

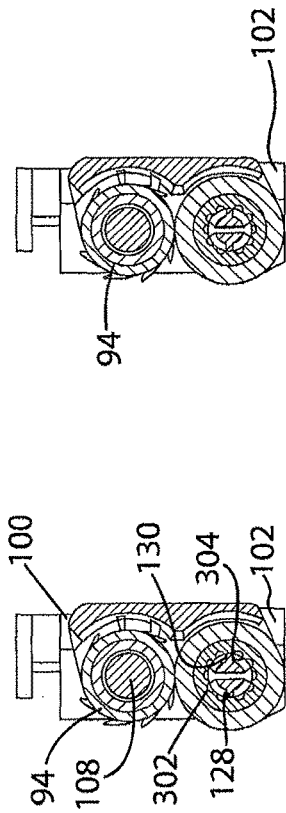


FIG. 18A

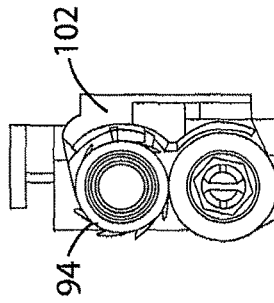


FIG. 18B

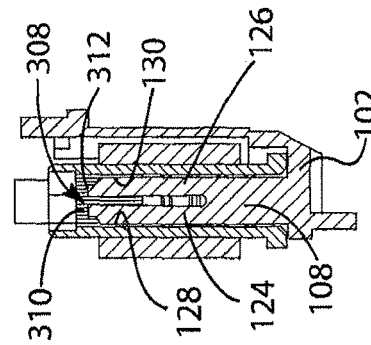


FIG. 18C

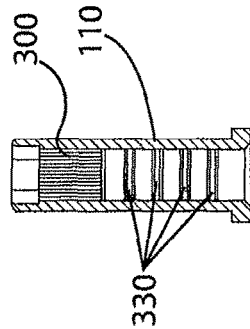


FIG. 17

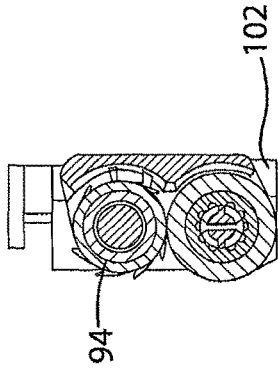


FIG. 19A

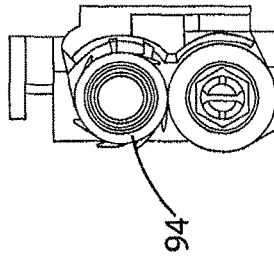


FIG. 19B

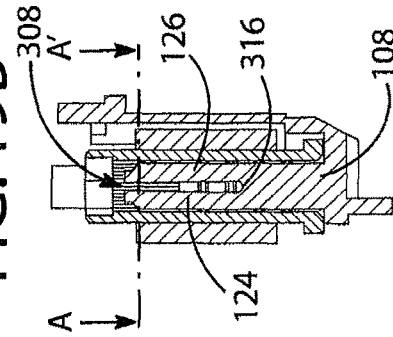


FIG. 19C

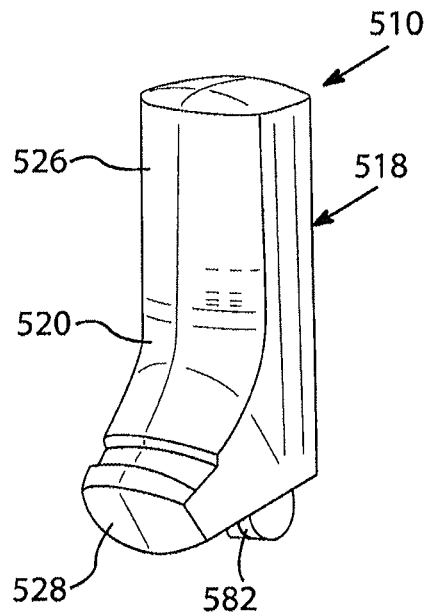


FIG. 21

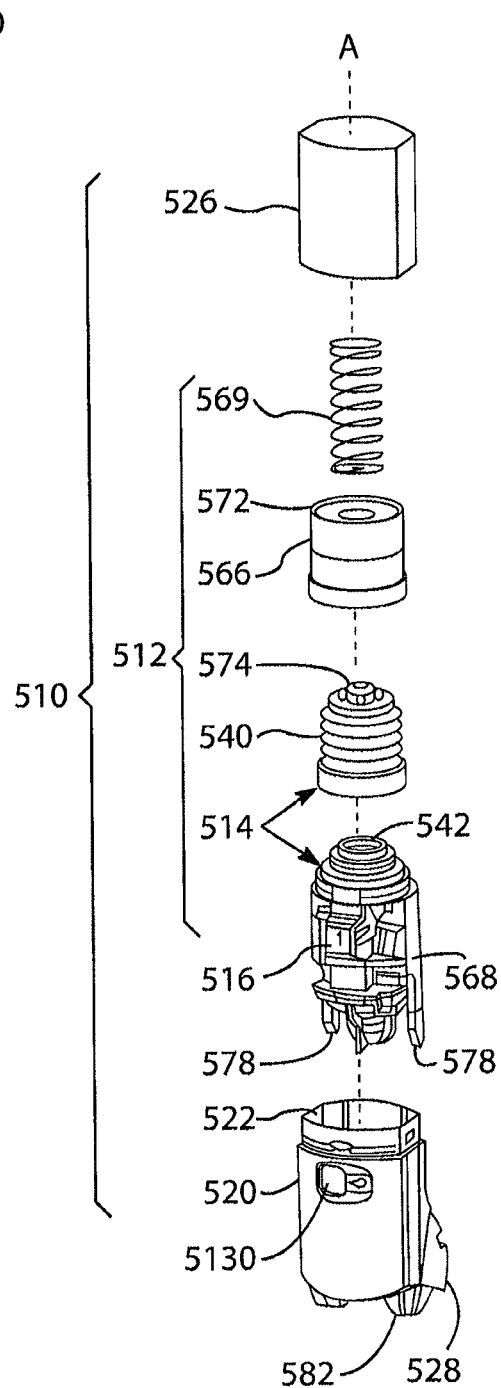


FIG. 22

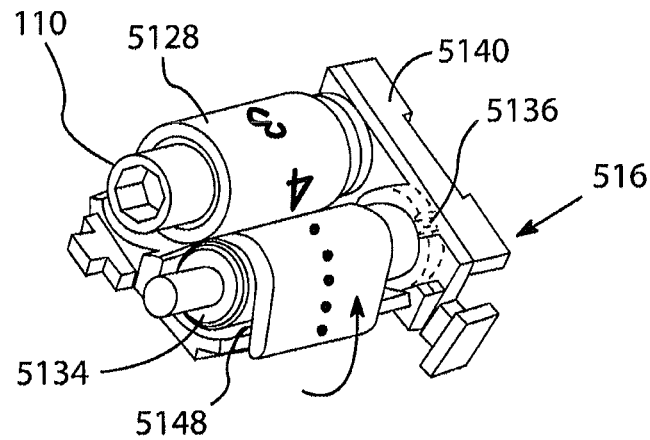


FIG. 23

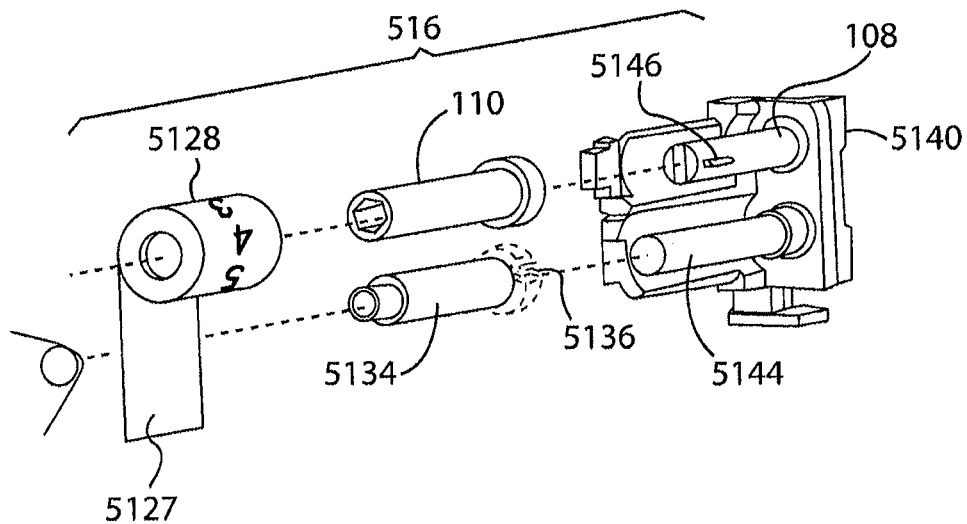


FIG. 24

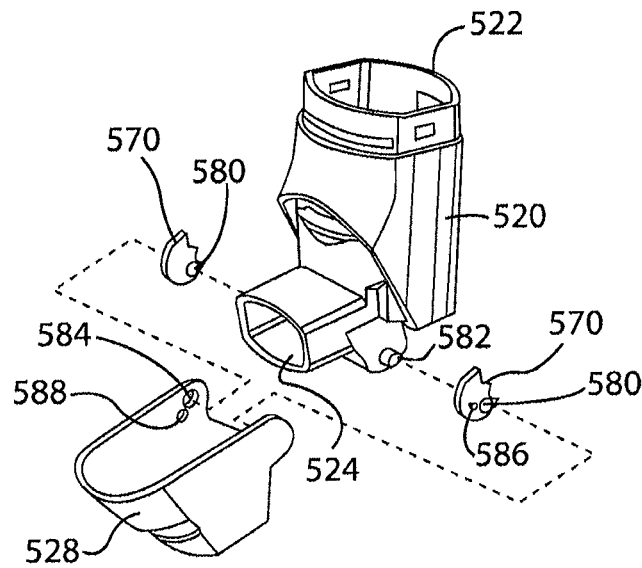


FIG. 25

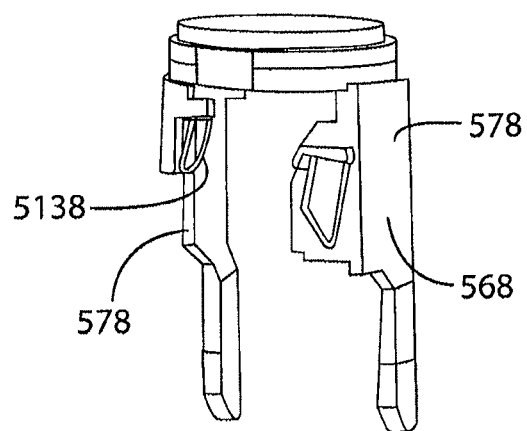


FIG. 26



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**DOSE COUNTER FOR INHALER HAVING  
AN ANTI-REVERSE ROTATION ACTUATOR**

**CROSS-REFERENCE TO RELATED  
APPLICATIONS**

This patent application is a continuation patent application of U.S. Non-Provisional patent application Ser. No. 14/699,584, filed Apr. 29, 2015, which is a continuation patent application of U.S. Non-Provisional patent application Ser. No. 14/103,353, filed Dec. 11, 2013, which is a divisional patent application of U.S. Non-Provisional patent application Ser. No. 13/110,532, filed May 18, 2011, now U.S. Pat. No. 8,978,966, issued Mar. 17, 2015, which claims priority to U.S. Provisional Patent Application No. 61/345,763, filed May 18, 2010, and U.S. Provisional Patent Application No. 61/417,659, filed Nov. 29, 2010, each of which is incorporated herein by reference in its entirety for any and all purposes.

**FIELD OF THE INVENTION**

The present invention relates to dose counters for inhalers, inhalers and methods of assembly thereof. The invention is particularly applicable to metered dose inhalers including dry power medicament inhalers, breath actuated inhalers and manually operated metered dose medicament inhalers.

**BACKGROUND OF THE INVENTION**

Metered dose inhalers can comprise a medicament-containing pressurised canister containing a mixture of active drug and propellant. Such canisters are usually formed from a deep-drawn aluminium cup having a crimped lid which carries a metering valve assembly. The metering valve assembly is provided with a protruding valve stem which, in use is inserted as a push fit into a stem block in an actuator body of an inhaler having a drug delivery outlet. In order to actuate a manually operable inhaler, the user applies by hand a compressive force to a closed end of the canister and the internal components of the metering valve assembly are spring loaded so that a compressive force of approximately 15 to 30N is required to activate the device in some typical circumstances.

In response to this compressive force the canister moves axially with respect to the valve stem and the axial movement is sufficient to actuate the metering valve and cause a metered quantity of the drug and the propellant to be expelled through the valve stem. This is then released into a mouthpiece of the inhaler via a nozzle in the stem block, such that a user inhaling through the outlet of the inhaler will receive a dose of the drug.

A drawback of self-administration from an inhaler is that it is difficult to determine how much active drug and/or propellant are left in the inhaler, if any, especially of the active drug and this is potentially hazardous for the user since dosing becomes unreliable and backup devices not always available.

Inhalers incorporating dose counters have therefore become known.

WO 98/028033 discloses an inhaler having a ratchet mechanism for driving a tape drive dose counter. A shaft onto which tape is wound has a friction clutch or spring for restraining the shaft against reverse rotation.

EP-A-1486227 discloses an inhaler for dry powered medicament having a ratchet mechanism for a tape dose counter which is operated when a mouthpiece of the inhaler

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is closed. Due to the way in which the mouthpiece is opened and closed, and actuation pawl of the device which is mounted on a yoke, travels a known long stroke of consistent length as the mouthpiece is opened and closed.

5 WO 2008/119552 discloses a metered-dose inhaler which is suitable for breath-operated applications and operates with a known and constant canister stroke length of 3.04 mm+/-0.255 mm. A stock bobbin of the counter, from which a tape is unwound, rotates on a shaft having a split pin intended to hold the stock bobbin taut. However, some dose counters do not keep a particularly reliable count, such as if they are dropped onto a hard surface.

10 More recently, it has become desirable to improve dose counters further and, in particular, it is felt that it would be useful to provide extremely accurate dose counters for manually-operated canister-type metered dose inhalers. Unfortunately, in these inhalers, it has been found in the course of making the present invention that the stroke length of the canister is to a very large extent controlled on each dose operation by the user, and by hand. Therefore, the stroke length is highly variable and it is found to be extremely difficult to provide a highly reliable dose counter for these applications. The dose counter must not count a dose when the canister has not fired since this might wrongly indicate to the user that a dose has been applied and if done repeatedly the user would throw away the canister or whole device before it is really time to change the device due to the active drug and propellant reaching a set minimum. Additionally, the canister must not fire without the dose counter counting because the user may then apply another dose thinking that the canister has not fired, and if this is done repeatedly the active drug and/or propellant may run out while the user thinks the device is still suitable for use according to the counter. It has also been found to be fairly difficult to assembly some known inhaler devices and the dose counters therefor. Additionally, it is felt desirable to improve upon inhalers by making them easily usable after they have been washed with water.

25 The present invention aims to alleviate at least to a certain extent one or more of the problems of the prior art.

**SUMMARY OF THE INVENTION**

According to a first aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a counter display arranged to indicate dosage information, a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input, wherein a regulator is provided which is arranged to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

30 The regulator is advantageous in that it helps prevent unwanted motion of the counter display if the counter is dropped.

According to a further aspect of the present invention, the regulator provides a resistance force of greater than 0.1 N against movement of the counter display. According to still a further aspect of the present invention, the resistance force is greater than 0.3 N. According to yet a further aspect of the present invention, the resistance force is from 0.3 to 0.4 N.

Preferably, the counter comprises a tape.

60 Preferably, the tape has dose counter indicia displayed thereon. The first station may comprise a region of the dose counter where tape is held which is located before a display location, such as a display window, for the counter indicia.

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The first station may comprise a first shaft, the tape being arranged on the first shaft and to unwind therefrom upon movement of the counter display.

The first shaft may be mounted for rotation relative to a substantially rotationally fixed element of the dose counter.

The regulator may comprise at least one projection which is arranged on one of the first shaft and the substantially rotationally fixed element and to engage incrementally with one or more formations on the other of the first shaft and the substantially rotationally fixed element.

At least two said projections may be provided. Exactly two said projections may be provided.

Each projection may comprise a radiused surface.

The at least one projection may be located on the substantially fixed element which may comprise a fixed shaft which is fixed to a main body of the dose counter, the first shaft being rotationally mounted to the fixed shaft.

Preferably, the fixed shaft has at least two resiliently flexible legs (or forks). Each leg may have at least one said projection formed in an outwardly facing direction thereon, said one or more formations being formed on an inwardly facing engagement surface of the first shaft, said at least one projection being arranged to resiliently engage said one or more formations. Preferably, a series of said formations are provided. An even number of said formations may be provided. Eight to twelve of said formations may be provided. In one embodiment, ten said formations are provided.

Each said formation may comprise a concavity formed on an engagement surface. Each concavity may comprise a radiused surface wall portion which preferably merges on at least one side thereof into a flat wall portion surface. The engagement surface may include a series of said concavities, and convex wall portions of the engagement surface may be formed between each adjacent two said concavities, each said convex wall portion comprising a convex radiused wall portion.

Each convex radiused wall portion of each convex wall portion may be connected by said flat wall portion surfaces to each adjacent concavity.

The fixed shaft may comprise a split pin with fork legs and each projection may be located on a said fork leg.

The first shaft may comprise a substantially hollow bobbin.

Said at least one formation may be located on an inner surface of the bobbin. In other embodiments it may be located on an outer surface thereof. Said engagement surface may extend partially along said bobbin, a remainder of the respective inner or outer surface having a generally smooth journal portion along at least a portion thereof.

The drive system may comprise a tooth ratchet wheel arranged to act upon a second shaft which is located at the second station, the second shaft being rotatable to wind the tape onto the second shaft.

The second shaft may be located on a main body of the dose counter spaced from and parallel to the first shaft.

The ratchet wheel may be fixed to the second shaft is arranged to rotate therewith. The ratchet wheel may be secured to an end of the second shaft and aligned coaxially with the second shaft.

The dose counter may include anti-back drive system which is arranged to restrict motion of the second shaft. The anti-back drive system may include a substantially fixed tooth arranged to act upon teeth of the ratchet wheel.

According to a further aspect of the present invention, a dose counter includes an anti-back drive system which is arranged to restrict motion of the second shaft in a tape winding direction.

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According to a further aspect of the present invention there is provided a shaft for holding counter tape in a dose counter for an inhaler, the shaft having an engagement surface including incrementally spaced formations located around a periphery thereof, the formations comprising a series of curved concavities and convex portions.

The shaft may comprise a hollow bobbin.

The engagement surface may be a generally cylindrical inwardly directed surface.

The engagement surface may include a flat surface wall portion joining each concavity and convex wall portion.

Each concavity may comprise a radiused wall portion.

Each convex wall portion may comprise a radiused wall portion.

Said concavities may be regularly spaced around a longitudinal axis of the shaft.

Said convex wall portions may be regularly spaced around a longitudinal axis of the shaft.

In some embodiments there may be from eight to twelve said concavities and/or convex wall portions regularly spaced around a longitudinal axis thereof.

One embodiment includes ten said concavities and/or convex wall portions regularly spaced around a longitudinal axis of the shaft.

According to a further aspect of the present invention there is provided a shaft and counter tape assembly for use in a dose counter for an inhaler, the assembly comprising a rotatable shaft and a counter tape which is wound around the shaft and is adapted to unwind therefrom upon inhaler actuation, the shaft having an engagement surface which includes incrementally spaced formations located around a periphery thereof.

According to a further aspect of the present invention there is provided an inhaler for the inhalation of medication and the like, the inhaler including a dose counter as in the first aspect of the present invention.

A preferred construction consists of a manually operated metered dose inhaler including a dose counter chamber including a dose display tape driven by a ratchet wheel which is driven in turn by an actuator pawl actuated by movement of a canister, the tape unwinding from a stock bobbin during use of the inhaler, a rotation regulator being provided for the stock bobbin and comprising a wavelike engagement surface with concavities which engage against control elements in the form of protrusions on resilient forks of a split pin thereby permitting incremental unwinding of the stock bobbin yet resisting excessive rotation if the inhaler is dropped onto a hard surface.

According to another aspect of the present invention there is provided a dose counter for a metered dose inhaler having a body arranged to retain a medicament canister of predetermined configuration for movement of the canister relative thereto; the dose counter comprising: an incremental counting system for counting doses, the incremental counting system having a main body, an actuator arranged to be driven in response to canister motion and to drive an incremental output member in response to canister motion, the actuator and incremental output member being configured to have predetermined canister fire and count configurations in a canister fire sequence, the canister fire configuration being determined by a position of the actuator relative to a datum at which the canister fires medicament and the count configuration being determined by a position of the actuator relative to the datum at which the incremental count system makes an incremental count, wherein the actuator is

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arranged to reach a position thereof in the count configuration at or after a position thereof in the canister fire configuration.

This arrangement has been found to be highly advantageous since it provides an extremely accurate dose counter which is suitable for use with manually operated metered dose inhalers. It has been found that dose counters with these features have a failure rate of less than 50 failed counts per million full canister activation depressions. It has been found in the course of making the present invention that highly reliable counting can be achieved with the dose counter counting at or soon after the point at which the canister fires. It has been is covered by the present inventors that momentum and motion involved in firing the canister, and in some embodiments a slight reduction in canister back pressure on the user at the time of canister firing, can very reliably result in additional further motion past the count point.

The actuator and incremental counting system may be arranged such that the actuator is displaced less than 1 mm, typically 0.25 to 0.75 mm, more preferably about 0.4 to 0.6 mm, relative to the body between its location in the count and fire configurations, about 0.48 mm being preferred. The canister, which can move substantially in line with the actuator, can reliably move this additional distance so as to achieve very reliable counting.

The incremental count system may comprise a ratchet mechanism and the incremental output member may comprise a ratchet wheel having a plurality of circumferentially spaced teeth arranged to engage the actuator.

The actuator may comprise an actuator pawl arranged to engage on teeth of the ratchet wheel. The actuator pawl may be arranged to be connected to or integral with an actuator pin arranged to engage and be depressed by a medicament canister bottom flange. The actuator pawl may be generally U-shaped having two parallel arms arranged to pull on a central pawl member arranged substantially perpendicular thereto. This provides a very reliable actuator pawl which can reliably pull on the teeth of the ratchet wheel.

The incremental count system may include a tape counter having tape with incremental dose indicia located thereon, the tape being positioned on a tape stock bobbin and being arranged to unwind therefrom.

The actuator and incremental output member may be arranged to provide a start configuration at which the actuator is spaced from the ratchet output member, a reset configuration at which the actuator is brought into engagement with the incremental output member during a canister fire sequence, and an end configuration at which the actuator disengages from the ratchet output during a canister fire sequence.

The actuator may be arranged to be located about 1.5 to 2.0 mm, from its location in the fire configuration, when in the start configuration, about 1.80 mm being preferred.

The actuator may be arranged to be located about 1.0 to 1.2 mm, from its location in the fire configuration, when in the reset configuration, about 1.11 mm being preferred.

The actuator may be arranged to be located about 1.1 to 1.3 mm, from its location in the fire configuration, when in the end configuration, about 1.18 mm being preferred.

These arrangements provide extremely reliable dose counting, especially with manually operated canister type metered dose inhalers.

The main body may include a formation for forcing the actuator to disengage from the incremental output member when the actuator is moved past the end configuration. The formation may comprise a bumped up portion of an other-

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wise generally straight surface against which the actuator engages and along which it is arranged to slide during a canister firing sequence.

The dose counter may include a counter pawl, the counter pawl having a tooth arranged to engage the incremental output member, the tooth and incremental output member being arranged to permit one way only incremental relative motion therebetween. When the incremental output member comprises a ratchet wheel, the tooth can therefore serve as an anti-back drive tooth for the ratchet wheel, thereby permitting only one way motion or rotation thereof.

The counter pawl may be substantially fixedly mounted on the main body of the incremental count system and the counter pawl may be arranged to be capable of repeatedly engaging equi-spaced teeth of the incremental output member in anti-back drive interlock configurations as the counter is operated. The counter pawl may be positioned so that the incremental output member is halfway, or substantially halfway moved from one anti-back drive interlock configuration to the next when the actuator and incremental output member are in the end configuration thereof. This is highly advantageous in that it minimises the risk of double counting or non-counting by the dose counter.

According to a further aspect of the invention there is provided an inhaler comprising a main body arranged to retain a medicament canister of predetermined configuration and a dose counter mounted in the main body.

The inhaler main body may include a canister receiving portion and a separate counter chamber, the dose counter being located within the main body thereof, the incremental output member and actuator thereof inside the counter chamber, the main body of the inhaler having wall surfaces separating the canister-receiving portion and the counter chamber, the wall surfaces being provided with a communication aperture, an actuation member extending through the communication aperture to transmit canister motion to the actuator.

According to a further aspect of the present invention there is a provided an inhaler for metered dose inhalation, the inhaler comprising a main body having a canister housing arranged to retain a medicament canister for motion therein, and a dose counter, the dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of a medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation located directly adjacent the actuation member.

This is highly advantageous in that the first inner wall canister support formation can prevent a canister from rocking too much relative to the main body of the inhaler. Since the canister may operate the actuation member of the dose counter, this substantially improves dose counting and avoids counter errors.

The canister housing may have a longitudinal axis which passes through a central outlet port thereof, the central outlet port being arranged to mate with an outer canister fire stem of a medicament canister, the inner wall canister support formation, the actuation member and the outlet port lying in a common plane coincident with the longitudinal axis. Accordingly, this construction may prevent the canister from rocking towards the position of the dose counter actuation member, thereby minimising errors in counting.

The canister housing may have a further inner canister wall support formation located on the inner wall opposite, or substantially opposite, the actuation member. Accordingly, the canister may be supported against rocking motion away from the actuator member so as to minimise count errors.

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The canister housing may be generally straight and tubular and may have an arrangement in which each said inner wall support formation comprises a rail extending longitudinally along the inner wall.

Each said rail may be stepped, in that it may have a first portion located towards a medicine outlet end or stem block of the canister housing which extends inwardly a first distance from a main surface of the inner wall and a second portion located toward an opposite end of the canister chamber which extends inwardly a second, smaller distance from the main surface of the inner wall. This may therefore enable easy insertion of a canister into the canister housing such that a canister can be lined up gradually in step wise function as it is inserted into the canister housing.

The inhaler may include additional canister support rails which are spaced around an inner periphery of the inner wall of the canister housing and which extend longitudinally therealong.

At least one of the additional rails may extend a constant distance inwardly from the main surface of the inner wall.

At least one of the additional rails may be formed with a similar configuration to the first inner wall canister support formation.

The dose counter may, apart from said at least a portion of the actuation member, be located in a counter chamber separate from the canister housing, the actuation member comprising a pin extending through an aperture in a wall which separates the counter chamber and the canister housing.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicaments having: a body for retaining a medicament store; the body including a dose counter, the dose counter having a moveable actuator and a return spring for the actuator, the return spring having a generally cylindrical and annular end; the body having a support formation therein for supporting said end of the return spring, the support formation comprising a shelf onto which said end is engageable and a recess below the shelf.

This shelf and recess arrangement is highly advantageous since it allows a tool (such as manual or mechanical tweezers) to be used to place the return spring of the actuator onto the shelf with the tool then being withdrawn at least partially via the recess.

The shelf may be U-shaped.

The support formation may include a U-shaped upstanding wall extending around the U-shaped shelf, the shelf and upstanding wall thereby forming a step and riser of a stepped arrangement.

The recess below the shelf may also be U-shaped.

At least one chamfered surface may be provided at an entrance to the shelf. This may assist in inserting the actuator and return spring into position.

A further aspect of the invention provides a method of assembly of an inhaler which includes the step of locating said end of said spring on the shelf with an assembly tool and then withdrawing the assembly tool at least partly via the recess. This assembly method is highly advantageous compared to prior art methods in which spring insertion has been difficult and in which withdrawal of the tool has sometimes accidentally withdrawn the spring again.

The cylindrical and annular end of the spring may be movable in a direction transverse to its cylindrical extent into the shelf while being located thereon.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament, the inhaler having a body for retaining a medicament store; and

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a dose counter, the dose counter having a moveable actuator and a chassis mounted on the body; the chassis being heat staked in position on the body. This is highly advantageous in that the chassis can be very accurately positioned and held firmly in place, thereby further improving counting accuracy compared to prior art arrangements in which some movement of the chassis relative to the body may be tolerated in snap-fit connections.

The chassis may have at least one of a pin or aperture heat staked to a respective aperture or pin of the body.

The chassis may have a ratchet counter output member mounted thereon.

The ratchet counter output member may comprise a ratchet wheel arranged to reel in incrementally a dose meter tape having a dosage indicia located thereon.

According to a further aspect of the present invention there is provided a method of assembling an inhaler including the step of heat staking the chassis onto the body. The step of heat staking is highly advantageous in fixedly positioning the chassis onto the body in order to achieve highly accurate dose counting in the assembled inhaler.

The method of assembly may include mounting a spring-returned ratchet actuator in the body before heat staking the chassis in place. The method of assembly may include pre-assembling the chassis with a dose meter tape prior to the step of heat staking the chassis in place. The method of assembly may include attaching a dose meter cover onto the body after the heat staking step. The cover may be welded onto the body or may in some embodiments be glued or otherwise attached in place.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament and having a body, the body have a main part thereof for retaining a medicament store; and a dose counter, the dose counter being located in a dose counter chamber of the body which is separated from the main part of the body, the dose counter chamber of the body having a dosage display and being perforated so as to permit the evaporation of water or aqueous matter in the dose counter chamber into the atmosphere.

This is highly advantageous since it enables the inhaler to be thoroughly washed and the dose counting chamber can thereafter dry out fully.

The display may comprise a mechanical counter display inside the dose counter chamber and a window for viewing the mechanical counter display. The mechanical counter display may comprise a tape. The perforated dose counter chamber may therefore enable reliable washing of the inhaler, if desired by the user, and may therefore dry out without the display window misting up.

The dose counter chamber may be perforated by a drain hole formed through an outer hole of the body. The drain hole may be located at a bottom portion of the body of the inhaler, thereby enabling full draining of the inhaler to be encouraged after washing when the inhaler is brought into an upright position.

According to a further aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a display tape arranged to be incrementally driven from a tape stock bobbin onto an incremental tape take-up drive shaft, the bobbin having an internal bore supported by and for rotation about a support shaft, at least one of the bore and support shaft having a protrusion which is resiliently biased into frictional engagement with the other of the bore and support shaft with longitudinally extending mutual frictional interaction. This arrangement may provide good friction for the bobbin, thereby improving tape counter



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display accuracy and preventing the bobbin from unwinding undesirably for example if the inhaler is accidentally dropped.

The support shaft may be forked and resilient for resiliently biasing the support shaft and bore into frictional engagement.

The support shaft may have two forks, or more in some cases, each having a radially extending protrusion having a friction edge extending therealong parallel to a longitudinal axis of the support shaft for frictionally engaging the bore of the support shaft with longitudinally extending frictional interaction therebetween.

The bore may be a smooth circularly cylindrical or substantially cylindrical bore.

Each of the above inhalers in accordance with aspects of the present invention may have a medicament canister mounted thereto.

The canister may comprise a pressurised metered dose canister having a reciprocally movable stem extending therefrom and movable into a main canister portion thereof for releasing a metered dose of medicament under pressure, for example by operating a metered dose valve inside the canister body. The canister may be operable by pressing by hand on the main canister body.

In cases in which one or more support rails or inner wall support formations are provided, the canister may at all times when within the canister chamber have a clearance of about 0.25 to 0.35 mm from the first inner wall support formation. The clearance may be almost exactly 0.3 mm. This clearance which may apply to the canister body itself or to the canister once a label has been applied, is enough to allow smooth motion of the canister in the inhaler while at the same time preventing substantial rocking of the canister which could result in inaccurate counting by a dose counter of the inhaler, especially when lower face of the canister is arranged to engage an actuator member of the dose counter for counting purposes.

According to a further aspect of the invention, a method of assembling a dose counter for an inhaler comprises the steps of providing a tape with dosing indicia thereon; providing tape positioning indicia on the tape; and stowing the tape while monitoring for the tape positioning indicia with a sensor. The method advantageously permits efficient and accurate stowing of the tape, e.g. by winding.

The dosing indicia may be provided as numbers, the tape positioning indicia may be provided as one or more lines across the tape. The stowing step comprises winding the tape onto a bobbin or shaft, and, optionally, stopping winding when the positioning indicia are in a predetermined position. The tape may be provided with pixelated indicia at a position spaced along the tape from the positioning indicia. The tape may also be provided with a priming dot.

According to a further aspect of the invention, a tape system for a dose counter for an inhaler has a main elongate tape structure, and dosing indicia and tape positioning indicia located on the tape structure. The tape positioning indicia may comprise at least one line extending across the tape structure. The tape system may comprise pixelated indicia located on the tape structure and spaced from the positioning indicia. The tape system may comprise a priming dot located on the tape structure. The positioning indicia may be located between the timing dot and the pixelated indicia. The main elongate tape structure may have at least one end thereof wound on a bobbin or shaft.

A further aspect of the invention provides a method of designing an incremental dose counter for an inhaler comprising the steps of calculating nominal canister fire and

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dose counter positions for a dose counter actuator of the inhaler; calculating a failure/success rate for dose counters built to tolerance levels for counting each fire of inhalers in which the dose counter actuators may be applied; and selecting a tolerance level to result in said failure/success rate to be at or below/above a predetermined value. This is highly advantageous in that it allows an efficient and accurate prediction of the reliability of a series of inhaler counters made in accordance with the design.

The method of designing may include selecting the failure/success rate as a failure rate of no more than one in 50 million. The method of designing may include setting an average count position for dose counters built to the tolerances to be at or after an average fire position thereof during canister firing motion. The method of designing may include setting the average count position to be about 0.4 to 0.6 mm after the average fire position, such as about 0.48 mm after. The method of designing may include setting tolerances for the standard deviation of the fire position in dose counters built to the tolerances to be about 0.12 to 0.16 mm, such as about 0.141 mm. The method of designing may include setting tolerances for the standard deviation of the count positions in dose counters built to the tolerances to be about 0.07 to 0.09 mm, such as about 0.08 mm. A further aspect of the invention provides a computer implemented method of designing an incremental dose counter for an inhaler which includes the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing in a production run a series of incremental dose counters for inhalers which comprises manufacturing the series of dose counters in accordance with the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing a series of incremental dose counters for inhalers, which comprises manufacturing the dose counters with nominal canister fire and dose count positions of a dose counter actuator relative to a dose counter chassis (or inhaler main body), and which includes building the dose counters with the average dose count position in the series being, in canister fire process, at or after the average canister fire position in the series.

According to a further aspect of the invention, the method provides fitting each dose counter in the series of incremental dose counters to a corresponding main body of an inhaler.

These aspects advantageously provide for the production run of a series of inhalers and dose counters which count reliably in operation.

According to a further aspect of the invention, an incremental dose counter for a metered dose inhaler has a body arranged to retain a canister for movement of the canister relative thereto, the incremental dose counter having a main body, an actuator arranged to be driven and to drive an incremental output member in a count direction in response to canister motion, the actuator being configured to restrict motion of the output member in a direction opposite to the count direction. This advantageously enables an inhaler dose counter to keep a reliable count of remaining doses even if dropped or otherwise jolted.

The output member may comprise a ratchet wheel. The actuator may comprise a pawl and in which the ratchet wheel and pawl are arranged to permit only one-way ratcheting motion of the wheel relative to the pawl. The dose counter may include an anti-back drive member fixed to the main body. In a rest position of the dose counter, the ratchet wheel is capable of adopting a configuration in which a back surface of one tooth thereof engages the anti-back drive member and the pawl is spaced from an adjacent back

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surface of another tooth of the ratchet wheel without positive drive/blocking engagement between the pawl and wheel.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be carried out in various ways and preferred embodiment of a dose counter, inhaler and methods of assembly, design and manufacture will now be described with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of a main body of an embodiment of an inhaler related to the invention together with a mouthpiece cap therefor;

FIG. 2 is a top plan view of the components as shown in FIG. 1;

FIG. 3A is a section on the plane 3A-3A in FIG. 2;

FIG. 3B is a view corresponding to FIG. 3A but with a dose counter fitted to the main body of the inhaler;

FIG. 4A is an exploded view of the inhaler main body, mouthpiece cap, dose counter and a dose counter window;

FIG. 4B is a view in the direction 4B in FIG. 4C of a spring retainer of the dose counter;

FIG. 4C is a top view of the spring retainer of FIG. 4B;

FIG. 5 is a bottom view of the assembled inhaler main body, mouthpiece cap, dose counter and dose counter window;

FIGS. 6A, 6B, 6C, 6D, 6E, 6F, 6G and 6H are various views of dose counter components of the inhaler;

FIGS. 7A and 7B are sectional views showing canister clearance inside the main body of the inhaler;

FIG. 7C is a further sectional view similar to that of FIG. 7B but with the canister removed;

FIG. 7D is a top plan view of the inhaler main body;

FIGS. 8A, 8B, 8C and 8D show the inhaler main body and dose counter components during assembly thereof;

FIG. 9 shows a sectional side view of a datum line for an actuator pawl of the dose counter;

FIGS. 10A, 10B, 10C, 10D, 10E and 10F show various side views of positions and configurations of the actuator pawl, a ratchet wheel, and a count pawl;

FIG. 11 shows distributions for tolerances of start, reset, fire, count and end positions for the actuator of the dose counter;

FIG. 12 is an enlarged version of part of FIG. 4A;

FIG. 13 shows an end portion of a tape of the dose counter;

FIG. 14 shows a computer system for designing the dose counter;

FIG. 15 is an isometric view of a stock bobbin modified in accordance with the present invention for use in the dose counter of the inhaler of FIGS. 1 to 14;

FIG. 16 shows an end view of the stock bobbin of FIG. 15;

FIG. 17 is a section through a longitudinal axis of the stock bobbin of FIGS. 15 and 16;

FIGS. 18A, 18B and 18C are views of the stock bobbin of FIGS. 15 to 17 mounted in the dose counter chassis of FIGS. 1 to 14, with the control elements of the forks of the second shaft (or split pin) having a profile slightly different to that in FIG. 6F, with the forks in a compressed configuration;

FIGS. 19A, 19B and 19C are views equivalent to FIGS. 18A to 18C but with the forks in a more expanded configuration due to a different rotational position of the stock bobbin;

FIG. 20 is an isometric view of the chassis assembled and including the stock bobbin of FIGS. 15 to 17 but excluding the tape for reasons of clarity;

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FIG. 21 is a view of a preferred embodiment of a dry powder inhaler in accordance with the present invention;

FIG. 22 is an exploded view of the inhaler of FIG. 21;

FIG. 23 is a view of a dose counter of the inhaler of FIG.

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FIG. 24 is an exploded view of the dose counter shown in FIG. 23;

FIG. 25 is an exploded view of parts of the inhaler of FIG. 21; and

FIG. 26 is a view of a yoke of the inhaler of FIG. 21.

#### DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a main body 10 of a manually operated metered dose inhaler 12 in accordance with an embodiment related to the present invention and having a mouthpiece cap 14 securable over a mouthpiece 16 of the main body.

The main body has a canister chamber 18 into which a canister 20 (FIG. 7A) is slideable. The canister 20 has a generally cylindrical main side wall 24, joined by a tapered section 26 to a head portion 28 having a substantially flat lower face 30 which has an outer annular drive surface 32 arranged to engage upon and drive an actuation pin 34 of a dose counter 36 as will be described. Extending centrally and axially from the lower face 30 is a valve stem 38 which is arranged to sealingly engage in a valve stem block 40 of the main body 10 of the inhaler 12. The valve stem block 40 has a passageway 42 leading to a nozzle 44 for directing the contents of the canister 20, namely active drug and propellant, towards an air outlet 46 of the inhaler main body 12. It will be appreciated that due to gaps 48 between the canister 20 and an inner wall 50 of the main body 10 of the inhaler 12 an open top 52 of the main body 10 forms an air inlet into the inhaler 12 communicating via air passageway 54 with the air outlet 46, such that canister contents exiting nozzle 44 mix with air being sucked by the user through the air passageway 54 in order to pass together through the air outlet and into the mouth of the user (not shown).

The dose counter 36 will now be described. The dose counter 36 includes an actuation pin 34 biased upwardly from underneath by a return spring 56 once installed in the main body 10. As best shown in FIGS. 4A, 6H and 8A, the pin 34 has side surfaces 58, 60 arranged to slide between corresponding guide surfaces 62, 64 located in a dose counter chamber 66 of the main body 10, as well as an end stop surface 68 arranged to engage a corresponding end stop 70 formed in the dose counter chamber 66 to limit upward movement of the pin 34. The pin 34 has a top part 72 which is circularly cylindrical and extends through an aperture 74 formed through a separator wall 76 which separates the canister chamber 18 from the dose counter chamber 66. The top part 72 of the pin 34 has a flat top surface 78 which is arranged to engage the outer annular drive surface 32 of the canister 20.

The actuation pin 34 is integrally formed with a drive or actuator pawl 80. The actuator pawl 80 has a generally inverted U-shape configuration, having two mutually spaced and parallel arms 82, 84 extending from a base portion of the actuation pin 34, each holding at respective distal ends 88 thereof opposite ends of a pawl tooth member 90 which extends in a direction substantially perpendicular to the arms 82, 84, so as to provide what may be considered a "saddle" drive for pulling on each of the 11 drive teeth 92 of a ratchet wheel 94 of an incremental drive system 96 or ratchet mechanism 96 of the dose counter 36. As shown for example in FIG. 10B, the pawl tooth member 90 has a sharp lower

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longitudinal side edge 98 arranged to engage the drive teeth 92, the edge-to-surface contact provided by this engagement providing very accurate positioning of the actuator pawl 80 and resultant rotational positioning of the ratchet wheel 94.

The dose counter 36 also has a chassis preassembly 100 which, as shown in FIGS. 4A and 6A, includes a chassis 102 having a first shaft 104 receiving the ratchet wheel 94 which is secured to a tape reel shaft 106, and a second shaft (or split pin) 108 which is parallel to and spaced from the first shaft 104 and which slidably and rotationally receives a tape stock bobbin 110.

As shown in FIG. 6B, when the inhaler has not been used at all, the majority of a tape 112 is wound on the tape stock bobbin 110 and the tape 112 has a series of regularly spaced numbers 114 displayed therealong to indicate a number of remaining doses in the canister 20. As the inhaler is repeatedly used, the ratchet wheel 94 is rotated by the actuator pawl 80 due to operation of the actuation pin 34 by the canister 20 and the tape 112 is incrementally and gradually wound on to the tape reel shaft 106 from the second shaft 108. The tape 112 passes around a tape guide 116 of the chassis 102 enabling the numbers 114 to be displayed via a window 118 in a dose counter chamber cover 120 having a dose marker 132 formed or otherwise located thereon.

As shown in FIGS. 6A and 6D, the second shaft 108 is forked with two forks 124, 126. The forks 124, 126 are biased away from one another. The forks have located thereon at diametrically opposed positions on the second shaft 108 friction or control elements 128, 130, one on each fork. Each control element extends longitudinally along its respective fork 124, 126 and has a longitudinally extending friction surface 132, 134 which extends substantially parallel to a longitudinal axis of the second shaft and is adapted to engage inside a substantially cylindrical bore 136 inside the tape stock bobbin 110. This control arrangement provided between the bore 136 and the control elements 128, 130 provides good rotational control for the tape stock bobbin 110 such that it does not unwind undesirably such as when the inhaler is dropped. The tape force required to unwind the tape stock bobbin 110 and overcome this friction force is approximately 0.1 N.

As can be seen in FIG. 6D, as well as FIGS. 6G and 10A to 10F, the chassis 102 is provided with an anti-back drive tooth 138 or count pawl 138 which is resiliently and substantially fixedly mounted thereto. As will be described below and as can be seen in FIGS. 10A to 10F, when the actuation pin 34 is depressed fully so as to fire the metered valve (not shown) inside the canister 20, the actuator pawl 80 pulls down on one of the teeth 92 of the ratchet wheel 94 and rotates the wheel 94 anticlockwise as shown in FIG. 6D so as to jump one tooth 92 past the count pawl 138, thereby winding the tape 112 a distance incrementally relative to the dose marker 122 on the dose counter chamber 120 so as to indicate that one dose has been used.

With reference to FIG. 10B, the teeth of the ratchet wheel 94 have tips 143 which are radiused with a 0.1 mm radius between the flat surfaces 140, 142. The ratchet wheel 94 has a central axis 145 which is 0.11 mm above datum plane 220 (FIG. 9). A top/nose surface 147 of the anti-back drive tooth 138 is located 0.36 mm above the datum plane 220. The distance vertically (i.e. transverse to datum plane 220—FIG. 9) between the top nose surface 147 of the anti-back drive tooth is 0.25 mm from the central axis 145 of the wheel 94. Bump surface 144 has a lateral extent of 0.20 mm, with a vertical length of a flat 145' thereof being 1 mm, the width of the bump surface being 1.22 mm (in the direction of the axis 145), the top 149 of the bump surface 144 being 3.02

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mm vertically below the axis 145, and the flat 145' being spaced a distance sideways (i.e. parallel to the datum plane 220) 2.48 mm from the axis 145. The top surface 78 of the pin 34 (FIG. 6H) is 11.20 mm above the datum plane 220 (FIG. 9) when the actuator pawl 80 and pin 34 are in the start configuration. The length of the valve stem 22 is 11.39 mm and the drive surface 32 of the canister 20 is 11.39 mm above the datum plane 220 when the canister is at rest waiting to be actuated, such that there is a clearance of 0.19 mm between the canister 20 and the pin 34 in this configuration.

FIGS. 10A and 10B show the actuator pawl 80 and ratchet wheel 94 and count pawl 138 in a start position in which the flat top 78 of the pin 34 has not yet been engaged by the outer annular drive surface 32 of the canister 20 or at least has not been pushed down during a canister depression.

In this "start" position, the count pawl 138 engages on a non-return back surface 140 of one of the teeth 92 of the ratchet wheel 94. The lower side edge 98 of the actuator pawl is a distance "D" (FIG. 9) 1.33 mm above datum plane 220 which passes through bottom surface or shoulder 41 of valve stem block 40, the datum plane 220 being perpendicular to a main axis "X" of the main body 10 of the inhaler 12 which is coaxial with the centre of the valve stem block bore 43 and parallel to a direction of sliding of the canister 20 in the main body 10 of the inhaler 12 when the canister is fired.

As shown in FIG. 10B, an advantageous feature of the construction is that the pawl tooth/actuator 90 acts as a supplementary anti-back drive member when the inhaler 12 is not being used for inhalation. In particular, if the inhaler 12 is accidentally dropped, resulting in a jolt to the dose counter 36 then, if the wheel 94 would try to rotate clockwise (backwards) as shown in FIG. 10B, the back surface 140 of a tooth will engage and be blocked by the tooth member 90 of the pawl 80. Therefore, even if the anti-back drive tooth 138 is temporarily bent or overcome by such a jolt, undesirable backwards rotation of the wheel 94 is prevented and, upon the next canister firing sequence, the pawl 90 will force the wheel 94 to catch up to its correct position so that the dose counter 36 continues to provide correct dosage indication.

FIG. 10C shows a configuration in which the actuator pawl 80 has been depressed with the pin 34 by the canister 20 to a position in which the side edge 98 of the pawl tooth member 90 is just engaged with one of the teeth 92 and will therefore upon any further depression of the pin 34 begin to rotate the wheel 94. This is referred to as a "Reset" position or configuration. In this configuration, the lower side edge 98 of the actuator 80 is 0.64 mm above the datum plane 220.

FIG. 10D shows a configuration in which the actuator pawl 80 has been moved to a position lower than that shown in FIG. 10C and in which the metered dose valve (not shown) inside the canister has at this very position fired in order to eject active drug and propellant through the nozzle 44. It will be noted that in this configuration the count pawl 138 is very slightly spaced from the back surface 140 of the same tooth 92 that it was engaging in the configuration of FIG. 10D. The configuration shown in FIG. 10D is known as a "Fire" configuration. In this configuration the lower side edge 98 of the actuator 80 is 0.47 mm below the datum plane 220.

FIG. 10E shows a further step in the sequence, called a "Count" position in which the actuator pawl 80 has rotated the ratchet wheel 94 by the distance circumferentially angularly between two of the teeth 92, such that the count pawl 138 has just finished riding along a forward surface 142 of one of the teeth 92 and has resiliently jumped over the tooth



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into engagement with the back surface **140** of the next tooth. Accordingly, in this "Count" configuration, a sufficiently long stroke movement of the pin **34** has occurred that the tape **112** of the dose counter **36** will just have counted down one dose. In this configuration, the lower side edge **98** of the actuator is 0.95 mm below the datum plane **220**. Accordingly, in this position, the actuator **80** generally, including edge **98**, is 0.48 mm lower than in the fire configuration. It has been found that, although the count configuration happens further on than the fire configuration, counting is highly reliable, with less than 50 failed counts per million. This is at least partially due to momentum effects and to the canister releasing some back pressure on the user in some embodiments as its internal metering valve fires.

In the configuration of FIG. **10F**, the pawl **80** has been further depressed with the pin **34** by the canister **20** to a position in which it is just disengaging from one of the teeth **92** and the actuator pawl **80** is assisted in this disengagement by engagement of one of the arms **84** with a bump surface **144** on the chassis **102** (see FIG. **6G**) and it will be seen at this point of disengagement, which is called an "End" configuration, the count pawl **138** is positioned exactly halfway or substantially halfway between two of the drive teeth **92**. This advantageously means therefore that there is a minimum chance of any double counting or non-counting, which would be undesirable. In the end configuration, the side edge **98** of the actuator is 1.65 mm below the datum plane **220**. It will be appreciated that any further depression of the actuator pawl **80** and pin **34** past the "End" configuration shown in FIG. **10F** will have no effect on the position of the tape **112** displayed by the dose counter **36** since the actuator pawl **80** is disengaged from the ratchet wheel **94** when it is below the position shown in FIG. **10F**.

As shown in FIGS. **7C** and **7D**, the inner wall **50** of the main body **10** is provided with a two-step support rail **144** which extends longitudinally along inside the main body and is located directly adjacent the aperture **74**. As shown in FIG. **7B** a diametrically opposed two-step support rail **146** is also provided and this diametrically opposed in the sense that a vertical plane (not shown) can pass substantially directly through the first rail **144**, the aperture **74**, a central aperture **148** of the valve stem block **40** (in which canister stem **25** is located) and the second two-step support rail **146**. As shown in FIG. **7A** and schematically in FIG. **7B**, the rails **144**, **146** provide a maximum clearance between the canister **20** and the rails **144**, **146** in a radial direction of almost exactly 0.3 mm, about 0.25 to 0.35 mm being a typical range. This clearance in this plane means that the canister **20** can only rock backwards and forwards in this plane towards away from the actuation pin **34**. A relatively small distance and this therefore prevents the canister wobbling and changing the height of the actuation pin **34** as to undesirably alter the accuracy of the dose counter **36**. This is therefore highly advantageous.

The inner wall **50** of the main body **10** is provided with two further two-step rails **150** as well as two pairs **152**, **154** of rails extending different constant radial amounts inwardly from the inner wall **50**, so as to generally achieve a maximum clearance of almost exactly 0.3 mm around the canister **20** for all of the rails **144**, **146**, **150**, **152**, **154** spaced around the periphery of the inner wall **50**, in order to prevent undue rocking while still allowing canister motion freely inside the inhaler **12**. It will be clear from FIG. **7C** for example that the two-step rails have a first portion near an outlet end **156** of the canister chamber **18**, the first portion having a substantially constant radial or inwardly-extending width, a first step **160** leading to a second portion **162** of the rail, the

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second portion **102** having a lesser radial or inwardly extending extent than the first portion **156**, and finally a second step **164** at which the rail merges into the main inner wall **50** main surface.

A method of assembling the inhaler **12** will now be described.

With reference to FIG. **8A**, the main body **10** of the inhaler **12** is formed by two or more plastics mouldings which have been joined together to the configuration shown.

As shown in FIG. **8B**, the actuator pawl **80** and pin **34** are translated forward into position into a pin receiving area **166** in the dose counter chamber **66** and the pin **34** and actuator **80** may then be raised until the pin **34** emerges through the aperture **74**.

Next, the return spring **56** may be inserted below the pin **34** and a generally cylindrical annular lower end **168** of the spring **56** may be moved by a tweezer or tweezer-like assembly tool (not shown) into engagement with a shelf **170** of a spring retainer **172** in the dose counter chamber **66**. The spring retainer **172** is U-shaped and the shelf **170** is U-shaped and has a recess **174** formed below it. As shown in FIGS. **4B**, **4C** and **12** shelf **170** includes three chamfer surfaces **176**, **178**, **180** arranged to assist in moving the lower end of the spring **168** into position onto the shelf using the assembly tool (not shown). Once the lower end of the spring **168** is in place, the assembly tool (not shown) can easily be removed at least partly via the recess **174** below the lower end **168** of the spring **56**.

The tape **112** is attached at one end (not shown) to the tape stock bobbin **110** and is wound onto the bobbin by a motor **200** (FIG. **13**) having a hexagonal output shaft **202** which engages in a hexagonal socket **204** (FIG. **6B**) of the bobbin. During winding, the tape is monitored by a sensor **206**, which may be in the form of a camera or laser scanner, which feeds data to a computer controller **205** for the motor **200**. The controller **205** recognises three positioning markers **210** in the form of lines across the tape **112** and stops the motor **202** when the tape **112** is nearly fully wound onto the bobbin **110**, such that the distal end **212** of the tape **112** can be secured, e.g. by adhesive, to the tape reel shaft **106**. The controller **205** also recognises a pixelated tape size marker **214** observed by the sensor **206** and logs in a stocking system data store **217** details of the tape **112** such as the number of numbers **114** on the tape, such as one hundred and twenty or two hundred numbers **114**. Next, the tape reel shaft is wound until an appropriate position of the lines **210** at which a priming dot **216** will, once the bobbin **110** and reel shaft **106** are slid onto the second shaft **108** and second shaft **104**, be in a position to be located in the window **118** when the inhaler **12** is fully assembled. In the embodiments, the bobbin **110** and reel shaft **106** may be slid onto the shafts **108**, **104** before the tape **112** is secured to the reel shaft **106** and the reel shaft may then be wound to position the priming dot **216**.

Next, the assembled dose counter components of the chassis preassembly **100** shown in FIG. **6B** may as shown in FIG. **8C** be inserted into the dose counter chamber **66**, with pins **182**, **184**, **186** formed on the main body **10** in the dose counter chamber **66** passing through apertures or slots **188**, **190**, **192** formed on the chassis **102**, such that the pins **182**, **184**, **186** extend through (or at least into) the apertures or slots **188**, **190**, **192**. With the chassis **102** being relatively firmly pushed towards the main body **10**, the pins **182**, **184**, **186** are then heat staked and the chassis **102** is therefore after this held very firmly in position in the main body and is unable to move, thereby assisting in providing great accuracy for the dose counter **36**. Next, as shown in FIG. **8D**, the

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dose counter chamber cover **120** may be fitted over the dose counter chamber **66** and may be secured in place such as by welding, with the priming dot **216** being displayed through the window.

The user can, when readying the inhaler **12** for first use, prime the inhaler by depressing the canister **20** three times which will bring the first number **114** on the tape into display through the window **118** in place of the priming dot **216**, the number **114** shown in FIG. **8D** being “200”, thereby indicating that 200 doses are remaining to be dispensed from the canister **20** and inhaler **12**.

As shown in FIG. **8D**, and in FIG. **5**, an open drain hole **194** is provided at the bottom of the dose counter chamber **66** by a substantially semi-circular cut-out or recess formation **196** in a lower surface **198** of the main body **10** of the inhaler. Accordingly, if the user (not shown) should decide to wash the main body **10** of the inhaler, for example after encountering an unhygienic situation or simply as a matter of choice, the drain hole **194** allows initial draining of water from inside the dose counter chamber **66** and also thereafter evaporation of water or any aqueous matter in the dose counter chamber **66** so that the window **118** does not mist up undesirably.

FIG. **14** shows a computer system **230** for designing the dose counter **36** and in particular for calculating distributions representative of average positions and standard deviations in a production series of inhalers of the start, reset, fire, count and end positions of the actuator lower side edge **98** relative to the datum plane **220** (FIG. **9**) and therefore of the actuator pawl **80** generally relative to the ratchet wheel **94**, chassis **102** and, when the inhaler **12** is fully assembled, the main body **10** of the inhaler **12**. The computer system **230** includes a data store **232**, a CPU **234**, an input device **236** (such as a keyboard or communication port) and an output device **238** (such as a communications port, display screen and/or printer). A user may enter data via the input device **236** which may be used by the CPU **234** in a mathematical calculation to predict count failure rates when the various dose counters are to be built in a series with dose counter positions set with given averages and standard deviations and taking into account any momentum/inertia effects and metering valve user-back-pressure reduction effect which will occur upon canister firing of a given type of canister. The computer system **230** is thus mathematically used to design the distributions. For the inhaler **12** described herein with the dose counter **36** and canister **20**, the distributions are designed as shown in FIG. **11**. The x axis shows distance of the lower side surface **98** of the actuator **80** above the datum plane **220** and the y axis is representative of the distribution. Thus, curve **240** shows that the start configuration has an average 1.33 mm above the datum plane **200** (standard deviation is 0.1 mm), curve **242** shows that the reset configuration has an average of 0.64 mm above the datum plane **220** (standard deviation is 0.082 mm), curve **244** shows the fire configuration has an average 0.47 mm below the datum plane **220** (standard deviation is 0.141 mm), curve **246** shows the count configuration has an average 0.95 mm below the datum plane **220** (standard deviation is 0.080 mm), and curve **248** shows the end configuration has an average of 1.65 mm below the datum plane **220** (standard deviation is 0.144 mm).

FIGS. **15** to **20** show a version of the inhaler modified in accordance with the present invention. In these drawings, the same reference numerals have been used to those in the earlier drawings to denote the equivalent components. The inhaler **12** is the same as that in FIGS. **1** to **14** apart from the following modifications.

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First, it can be seen that there is a modification in that the drive teeth **92** of the ratchet wheel **94** have a different profile to that in FIGS. **1** to **14**. There are also only nine ratchet teeth **94** in this embodiment instead of eleven.

Additionally, as shown in FIGS. **18C** and **19C**, the control elements **128**, **130** on the forks **124**, **126** of the second shaft **108** have a tapered profile which is different to the profile of the control elements **128**, **130** shown in FIG. **6F**. Either profile can be used in the embodiment of FIGS. **15** to **20** however.

Furthermore, as shown in FIG. **15**, the tape stock bobbin **110** has an inwardly facing generally cylindrical engagement surface **300** with a wavelike form extending partially therealong. The engagement surface **300** has a cross-section **301** perpendicular to the longitudinal length of the stock bobbin **110** which is constant therealong. This cross-section **301** can be seen in FIG. **16** and consists of a series of ten regularly spaced concavities **302** and ten convex wall portions **304**. The convex wall portions **304** are equi-spaced between the concavities **302**. Each concavity **302** has a radius of 0.2 mm. Each convex wall portion **304** also has a radius of 0.2 mm. Finally, the cross section **301** also includes flat wall portions **306** between all of the radiused wall portions of the concavities **302** and convex wall portions **304**. The geometry of the cross-section **301** is therefore defined by the radii of the concavities **302** and convex wall portions **304**, the flat wall portions **306** and the fact that there are ten concavities **302** and convex wall portions **304**.

The minor diameter of the engagement surface **300**, i.e. between the tips of opposite convex wall portions **304**, is 2.46 mm. The major diameter of the engagement surface **300**, i.e. between the outermost portions of the concavities **302**, is 2.70 mm. The undeformed tip to tip maximum diameter of the forks **124**, **126** of the split pin (the second shaft) **108**, i.e. in the region of the maximum radial extent of the control elements **128**, **130**, is 3.1 millimetres and it will therefore be appreciated that the forks **124**, **126** are resiliently compressed once the stock bobbin **110** has been assembled onto the split pin **108** in all rotational configurations of the stock bobbin **110** relative to the split pin **108**. The minimum gap between the forks **124**, **126** in the plane of the cross sections of FIGS. **18C** and **19C** is 1 mm when the split pin **108** is in the undeformed, pre-inserted state. When the split pin **108** is at maximum compression, as shown in FIGS. **18A** to **18C** when the control elements **128**, **130** are shown to be engaged on top of the convex wall portions **304**, the gap **308** between the tips **310**, **312** of the forks **124**, **126** is 0.36 mm. On the other hand, when the split pin **108** is at minimum compression (once inserted into the stock bobbin) as shown in FIGS. **19A** to **19C**, when the control elements **128**, **130** rest in the concavities **302**, the gap between the tips **310**, **312** of the forks **124**, **126** is 0.6 mm. The control elements **128**, **130** are outwardly radiused with a radius also of 0.2 mm such that they can just rest on the concavities **302** with full surface contact (at least at an axial location on the split pin where the tapered control elements are at their maximum radial extent), without rattling in, locking onto or failing to fit in the concavities **302**. The radii of the control elements **128**, **130** is therefore preferably substantially the same as the radii of the concavities **302**.

It will be appreciated that whereas FIGS. **18B** and **19B** are end views along the coaxial axis of the stock bobbin **110** and split pin **108**, FIGS. **18A** and **19A** are cross-sections. FIG. **19A** is a section on the plane A-A' in FIG. **19C** and FIG. **18A** is a section at the same plane, but of course with the stock bobbin **110** rotated relative to the split pin **108**.

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As the inhaler 12 is used and the ratchet wheel 94 rotates in order to count used doses, the stock bobbin rotates incrementally through rotational positions in which rotation is resisted, i.e. due to increasing compression of the split pin 108 at such rotational positions, and rotational positions in which rotation is promoted, i.e. due to decreasing compression of the split pin 108 at such rotational positions and this may involve a click forward of the stock bobbin 110 to the next position equivalent to that in FIGS. 19A to 19C in which the control elements 128, 130 of the split pin art located in the concavities 302. This functionality firstly allows the stock bobbin to unwind during use as required, but also prevents the tape 112 from loosening during transit if the inhaler 12 is dropped, such as onto a hard surface. This is highly advantageous, since the tape 11 is prevented from moving to a position in which it will give an incorrect reading regarding the number of doses in the canister.

During compression and expansion of the forks in the radial direction between the two configurations shown in FIGS. 18C and 19C, the forks 124, 126 rotate about a point 316 on the split pin where the forks 124, 126 come together. This rotational action means that there is a camming action between the forks 124, 126 and the engagement surface 300 without significant friction but, nevertheless, the resilient forces provided by the regulator formed by the engagement surface 300 and forks 124, 126 are able to regulate unwinding of the tape such that it does not easily occur during transit or if the inhaler 12 is dropped. It has been found during testing that a force of 0.3 to 0.4 N needs to be applied to the tape 112 to overcome the regulator at the stock bobbin 110. 0.32 N is achieved with the control elements 128 having the profile shown in FIG. 19C and 0.38 N is achieved with the profile of the control elements 128 altered to be as shown as described with reference to FIG. 6F. These forces are substantially higher than the 0.1 N force mentioned above and undesirable movement of the tape is substantially avoided even if the inhaler is dropped onto a hard surface. The modified arrangement of FIGS. 15 to 20 does not provide this force "constantly" such that there is overall not an undesirably high friction of the tape 112 as it passes over the other components of the dose counter because, due to the incremental nature of the resilient forces at the regulator, the tape 112 can incrementally relax as it slides over the stationary chassis components.

Instead of having ten concavities 302 and convex wall portions 304, other numbers may be used, such as 8 or 12. However, it is preferred to have an even number, especially since two control elements 128, 130 are provided, so that all of the control elements 128, 130 will expand and contract simultaneously. However, other arrangements are envisaged with 3 or more forks and the number of concavities/convex wall portions may be maintained as an integer divisible by the number of forks to maintain a system with simultaneous expansion/contraction. For example, the use of 9, 12 or 15 concavities/convex wall portions with 3 forks is envisaged.

Instead of having the engagement surface 300 on the inside of the stock bobbin 110, it could be placed on the outside of the stock bobbin 110 so as to be engaged by flexible external legs/pawls or similar.

It will be noted that the regulator provided by the engagement surface 300 and forks 124, 126 does not only allow rotation of the stock bobbin in one direction as is the case with the ratchet wheel 94. Rotation in both directions is possible, i.e. forwards and backwards. This means that during assembly, the stock bobbin 110 can be wound backwards during or after fitting the bobbin 100, shaft 106 and tape 112 onto the carriage 102, if desired.

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The stock bobbin 110 and the carriage 102 including the split pin 108 are both moulded of polypropylene material.

It will be seen from FIG. 16 that the cross-sectional shape 301 is not symmetrical within the hexagonal socket 204. This has enabled the hexagonal socket 204 to be maintained at a useful size while still allowing the desired size and geometry of the cross section 301 to fit without interfering with the hexagonal shape of the hexagonal socket 204 and also permits moulding to work during manufacture.

As shown in FIG. 17, the stock bobbin 110 has a series of four circumferential ribs 330 inside it and a spaced therealong. These hold the stock bobbin 110 on the correct side of the mould tool during moulding.

FIGS. 21 and 22 show a preferred embodiment in accordance with the invention of an inhaler 510 for dispensing a dry-powdered medicament in metered doses for patient inhalation. The inhaler 510 is as disclosed in FIGS. 1 to 16 or EP-A-1330280, the contents of which are hereby fully incorporated herein by reference, but with the stock bobbin 110 and second shaft 108 of the dose counter 516 modified so as to be as in FIGS. 15 to 20 hereof. Thus, the dry powder inhaler 510 generally includes a housing 518, and an assembly 512 received in the housing (see FIG. 21). The housing 518 includes a case 520 having an open end 522 and a mouthpiece 524 (FIG. 25) for patient inhalation, a cap 526 secured to and closing the open end 522 of the case 520, and a cover 528 pivotally mounted to the case 520 for covering the mouthpiece 524. As shown in FIG. 22, the inhaler 510 also includes an actuation spring 569, first yoke 566 with opening 572, bellows 540 with crown 574, a reservoir 514, second yoke 568 with hopper 542 and dose counter 516 mounted thereto, and case 520 has transparent window 5130 thereon for viewing dose counter tape indicia 5128. The dose metering system also includes two cams 570 mounted on the mouthpiece cover 528 and movable with the cover 528 between open and closed positions. The cams 570 each include an opening 580 for allowing outwardly extending hinges 582 of the case 520 to pass therethrough and be received in first recesses 584 of the cover 528. The cams 570 also include bosses 586 extending outwardly and received in second recesses 588 of the cover 528, such that the cover 528 pivots about the hinges 582 and the cams 570 move with the cover 528 about the hinges 582. As described in EP-A-1330280, cams 570 act upon cam followers 578 to move second yoke 568 up and down and thereby operate dose counter by engagement of pawl 5138 on the second yoke 568 with teeth 5136. Remaining components of the inhaler are provided as, and operate as described, in EP-A-1330280.

The dose counting system 516 therefore includes a ribbon or tape 5128 (FIGS. 23 & 24), having successive numbers or other suitable indicia printed thereon, in alignment with a transparent window 5130 provided in the housing 18 (see FIG. 22). The dose counting system 516 includes the rotatable stock bobbin 110 (as described above), an indexing spool 5134 rotatable in a single direction, and the ribbon 5128 rolled and received on the bobbin 110 and having a first end 5127 secured to the spool 5134, wherein the ribbon 5128 unrolls from the bobbin 110 so that the indicia are successively displayed as the spool 5134 is rotated or advanced. In FIGS. 23 and 24 the wavelike engagement surface 300 of the bobbin 110 is not shown for the purposes of clarity.

The spool 134 is arranged to rotate upon movement of the yokes 566, 568 to effect delivery of a dose of medicament from reservoir 514, such that the number on the ribbon 5128 is advanced to indicate that another dose has been dispensed by the inhaler 510. The ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase or



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decrease upon rotation of the spool 5134. For example, the ribbon 5128 can be arranged such that the numbers, or other suitable indicia, decrease upon rotation of the spool 5134 to indicate the number of doses remaining in the inhaler 510. Alternatively, the ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase upon rotation of the spool 5134 to indicate the number of doses dispensed by the inhaler 10.

The indexing spool 5134 includes radially extending teeth 5136, which are engaged by pawl 5138 extending from a cam follower 578 of the second yoke 568 upon movement of the yoke to rotate, or advance, the indexing spool 5134. More particularly, the pawl 5138 is shaped and arranged such that it engages the teeth 5136 and advances the indexing spool 5134 only upon the mouthpiece cover 528 being closed and the yokes 566, 568 moved back towards the cap 526 of the housing 518.

The dose counting system 516 also includes a chassis 5140 that secures the dose counting system to the hopper 542 and includes shafts 108, 5144 for receiving the bobbin 110 and the indexing spool 5134. As described above with reference to FIGS. 1 to 20, the bobbin shaft 108 is forked and includes radially nubs 5146 for creating a resilient resistance to rotation of the bobbin 110 on the shaft 108 by engaging with the wavelike engagement surface 300 inside the bobbin 110. A clutch spring 5148 is received on the end of the indexing spool 5134 and locked to the chassis 5140 to allow rotation of the spool 5134 in only a single direction.

Various modifications may be made to the embodiment shown without departing from the scope of the invention as defined by the accompanying claims as interpreted under patent law.

What is claimed is:

1. A dose counter for an inhaler, the dose counter having a counter display arranged to indicate dosage information, a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input, wherein a regulator is provided which is arranged to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

2. The dose counter as claimed in claim 1 in which the counter display comprises a tape.

3. The dose counter as claimed in claim 2 in which the tape has dose counter indicia displayed thereon.

4. The dose counter as claimed in claim 2 wherein the first station comprises a first shaft, the tape being arranged on the first shaft and to unwind therefrom upon movement of the counter display.

5. The dose counter as claimed in claim 4 in which the first shaft is mounted for rotation relative to a substantially rotationally fixed element of the dose counter.

6. The dose counter as claimed in claim 5 in which the regulator comprises at least one projection on one of the first shaft and the substantially rotationally fixed element, which is arranged to engage incrementally with one or more formations on the other of the substantially rotationally fixed element and the first shaft.

7. The dose counter as claimed in claim 6 in which at least two said projections are provided.

8. The dose counter as claimed in claim 6 in which exactly two said projections are provided.

9. The dose counter as claimed in claim 6 in which each projection comprises a radiused surface.

10. The dose counter as claimed in claim 6 in which the at least one projection is located on the substantially rota-

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tionally fixed element which comprises a fixed shaft which is fixed to the main body of the dose counter, the first shaft being rotationally mounted to the fixed shaft.

11. The dose counter as claimed in claim 10 in which the fixed shaft has at least two flexible legs, and each leg has at least one said projection formed in an outwardly facing direction thereon, said one or more formations being formed on an inwardly facing engagement surface of the first shaft, said at least one projection being arranged to resiliently engage said one or more formations.

12. The dose counter as claimed in claim 10 in which the fixed shaft comprises a split pin with fork legs and in which each projection is located on a said fork leg.

13. The dose counter as claimed in claim 6 in which a series of said formations are provided.

14. The dose counter as claimed in claim 6 in which an even number of said formations is provided.

15. The dose counter as claimed in claim 6 in which from eight to twelve of said formations are provided.

16. The dose counter as claimed in claim 15 in which ten of said formations are provided.

17. The dose counter as claimed in claim 6 in which each said formation comprises a concavity formed on an engagement surface.

18. The dose counter as claimed in claim 17 in which each concavity comprises a radiused surface wall portion which merges on at least one side thereof into a flat wall portion surface.

19. The dose counter as claimed in claim 18 in which the engagement surface includes a series of said concavities and in which convex wall portions of the engagement surface are formed between each adjacent two said concavities, each said convex wall portion comprising a convex radiused wall portion.

20. The dose counter as claimed in claim 19 in which each convex radiused wall portion of each convex wall portion is connected by said flat wall portion surfaces to each concavity which is adjacent thereto.

21. The dose counter as claimed in claim 4 in which the first shaft comprises a substantially hollow bobbin.

22. The dose counter as claimed in claim 21 in which said one or more formations are located on an inner surface of the bobbin.

23. The dose counter as claimed in claim 4 wherein the drive system comprises a tooth ratchet wheel arranged to act upon a second shaft which is located at the second station, the second shaft being rotatable to wind the tape onto the second shaft.

24. The dose counter as claimed in claim 23 in which the second shaft is located on the main body of the dose counter spaced from and parallel to the first shaft.

25. The dose counter as claimed in claim 23 in which the tooth ratchet wheel is fixed to the second shaft and is arranged to rotate therewith.

26. The dose counter as claimed in claim 23 which includes an anti-back drive system which is arranged to restrict motion of the second shaft in a tape winding direction.

27. The dose counter as claimed in claim 1 in which the regulator provides a resistance force of greater than 0.1 N against movement of the counter display.

28. The dose counter as claimed in claim 27 in which the resistance force is greater than 0.3 N.

29. The dose counter as claimed in claim 27 in which the resistance force is from 0.3 to 0.4 N.

\* \* \* \* \*

## **EXHIBIT 5**

U 8079874



# THE UNITED STATES OF AMERICA

**TO ALL TO WHOM THESE PRESENTS SHALL COME:**

**UNITED STATES DEPARTMENT OF COMMERCE**

**United States Patent and Trademark Office**

**February 26, 2021**

**THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM  
THE RECORDS OF THIS OFFICE OF:**

**U.S. PATENT: 10,695,512**

**ISSUE DATE: June 30, 2020**

**By Authority of the**

**Under Secretary of Commerce for Intellectual Property  
and Director of the United States Patent and Trademark Office**



**P. R. GRANT**  
**Certifying Officer**



(12) **United States Patent**  
**Walsh et al.**

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(54) **DOSE COUNTER FOR INHALER HAVING AN ANTI-REVERSE ROTATION ACTUATOR**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 302 days.  
 This patent is subject to a terminal disclaimer.

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**Related U.S. Application Data**

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**G06M 1/24** (2006.01)  
**A61M 11/00** (2006.01)

(52) **U.S. Cl.**  
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(58) **Field of Classification Search**  
 CPC ..... A61M 15/0078; A61M 15/0025; A61M 15/0026; A61M 15/007; A61M 15/0071  
 (Continued)

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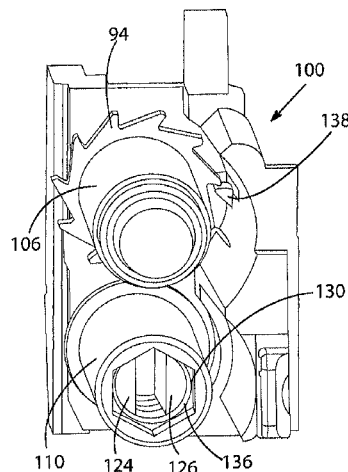
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(57) **ABSTRACT**

An inhaler includes a main body having a canister housing, a medicament canister retained in a central outlet port of the canister housing, and a dose counter having an actuation member for operation by movement of the medicament canister. The canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall. The canister housing  
 (Continued)



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has a longitudinal axis X which passes through the center of the central outlet port. The first inner wall canister support formation, the actuation member, and the central outlet port lie in a common plane coincident with the longitudinal axis X such that the first inner wall canister support formation protects against unwanted actuation of the dose counter by reducing rocking of the medicament canister relative to the main body of the inhaler.

## 6 Claims, 17 Drawing Sheets

## Related U.S. Application Data

continuation of application No. 14/103,324, filed on Dec. 11, 2013, now Pat. No. 9,463,289, which is a division of application No. 13/110,532, filed on May 18, 2011, now Pat. No. 8,978,966.

- (60) Provisional application No. 61/417,659, filed on Nov. 29, 2010, provisional application No. 61/345,763, filed on May 18, 2010.

## (52) U.S. Cl.

CPC ..... *A61M 15/009* (2013.01); *A61M 15/0025* (2014.02); *A61M 15/0026* (2014.02); *A61M 15/0065* (2013.01); *A61M 15/0071* (2014.02); *G06M 1/246* (2013.01); *A61M 2202/064* (2013.01); *A61M 2205/6063* (2013.01); *A61M 2207/00* (2013.01); *A61M 2207/10* (2013.01); *Y10T 29/49* (2015.01); *Y10T 29/49764* (2015.01); *Y10T 29/49826* (2015.01)

## (58) Field of Classification Search

USPC ..... 128/203.12  
See application file for complete search history.

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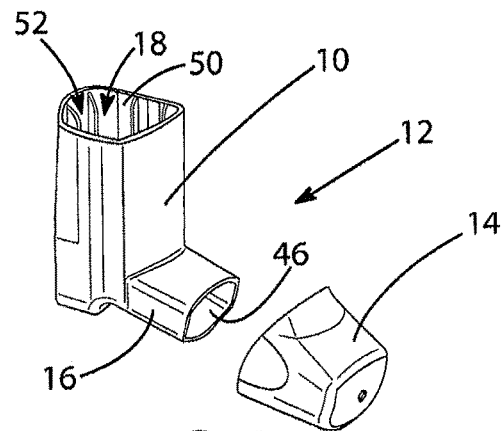


FIG. 1

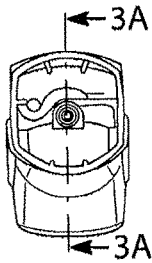


FIG. 2

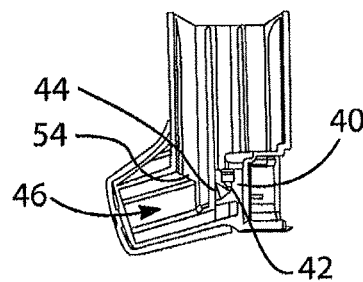


FIG. 3A

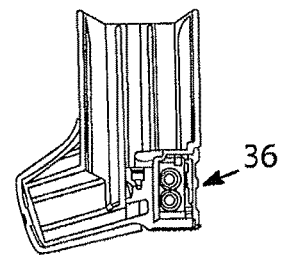


FIG. 3B

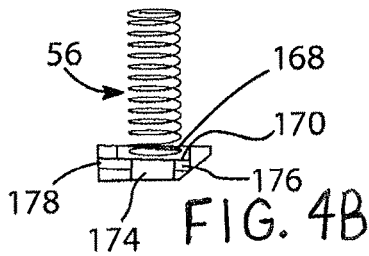


FIG. 4B

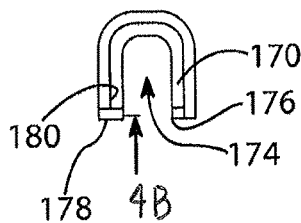


FIG. 4C

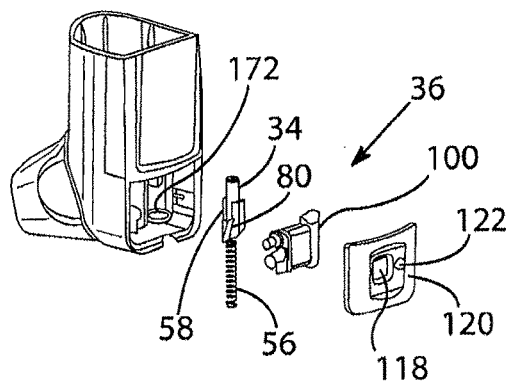


FIG. 4A

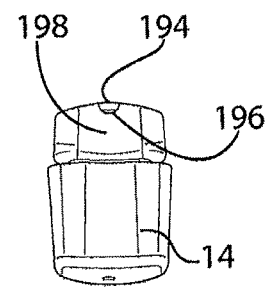


FIG. 5

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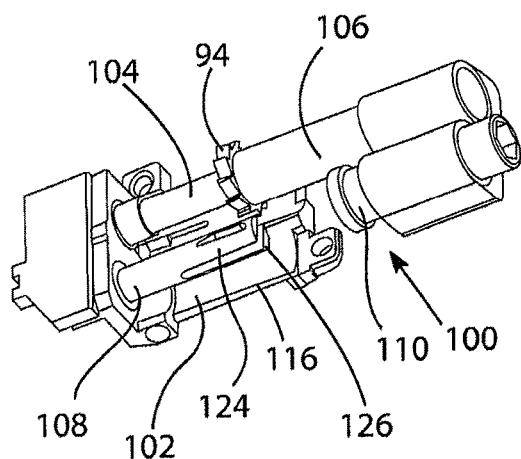


FIG. 6A

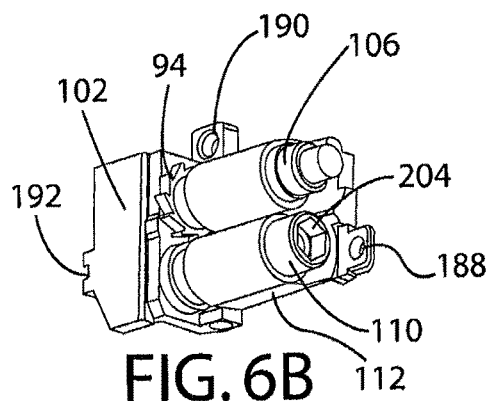


FIG. 6B

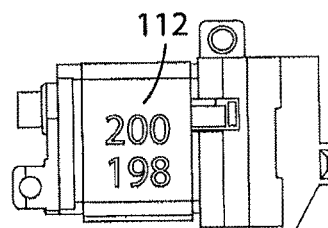


FIG. 6C

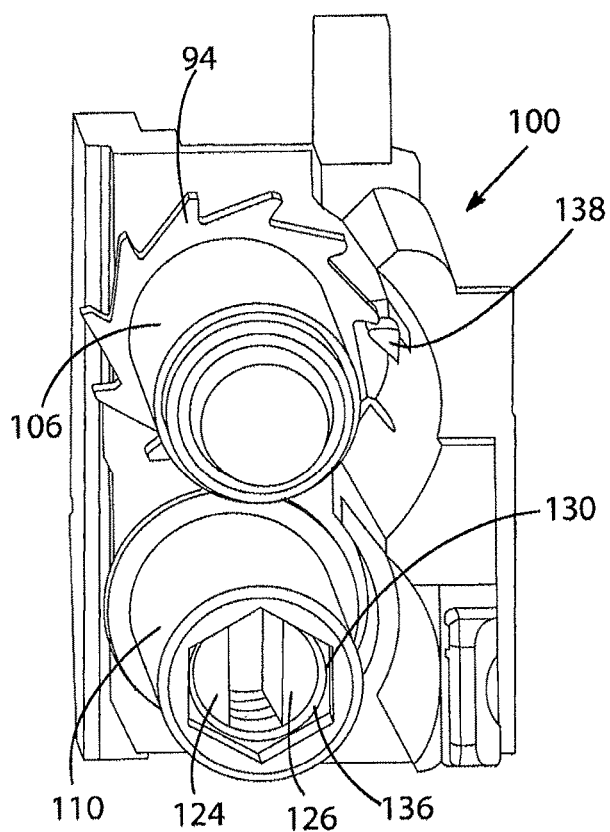


FIG. 6D

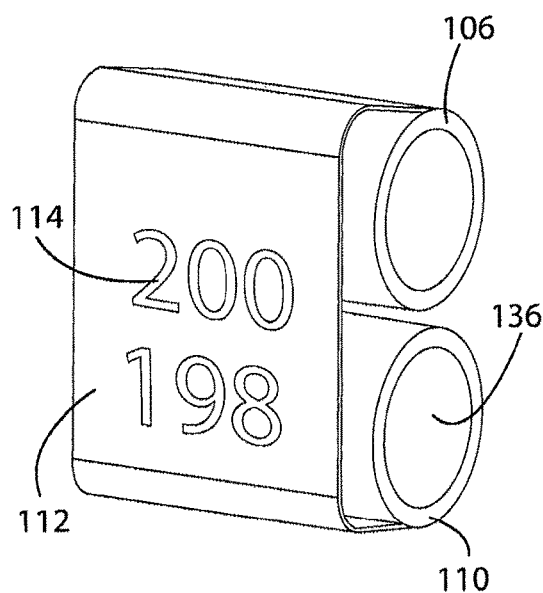


FIG. 6E

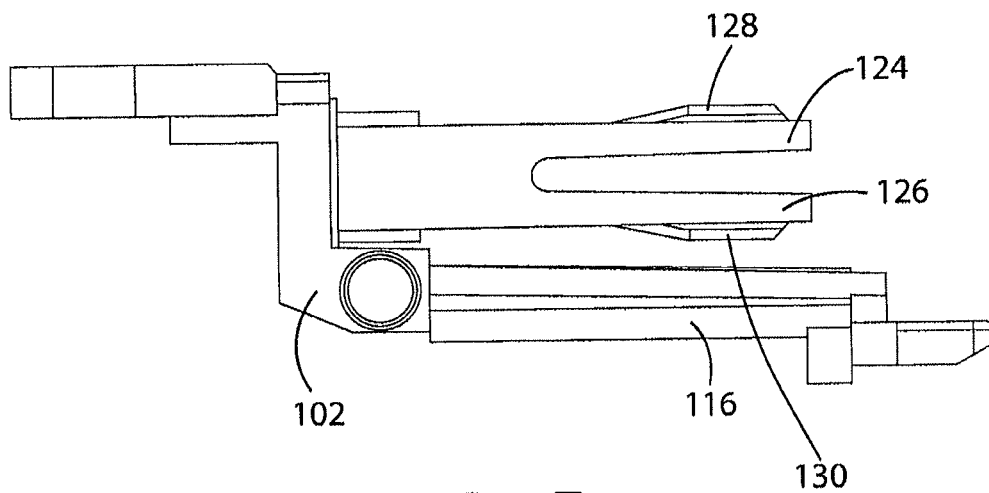


FIG. 6F

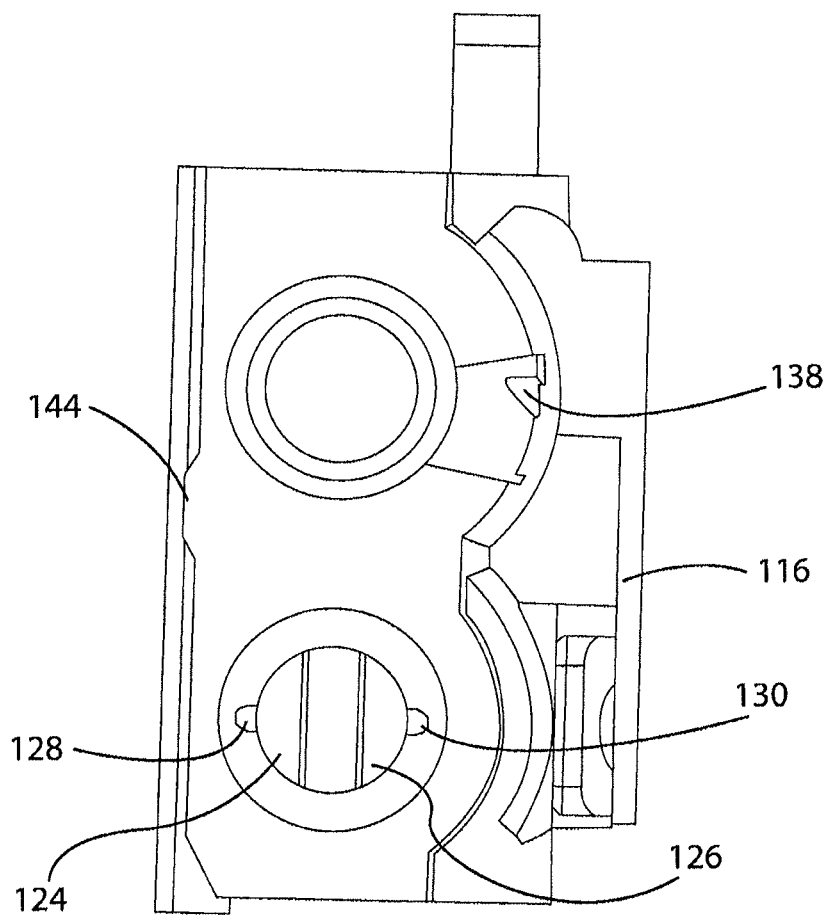
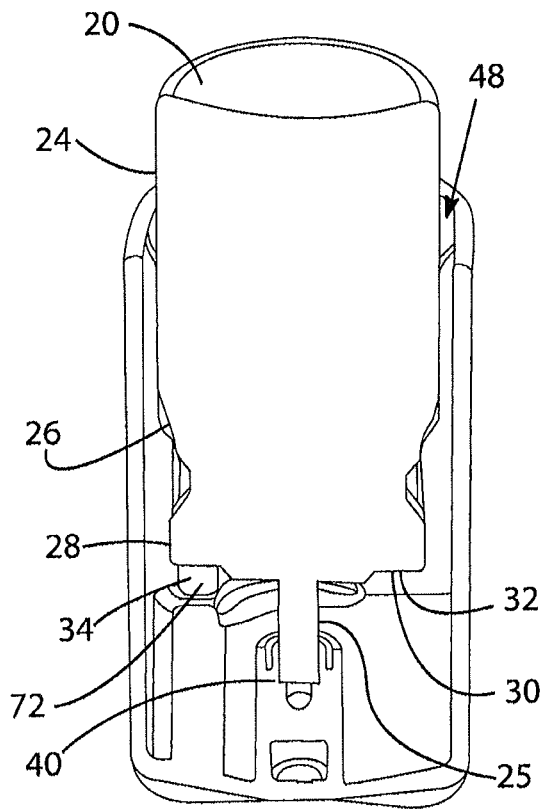
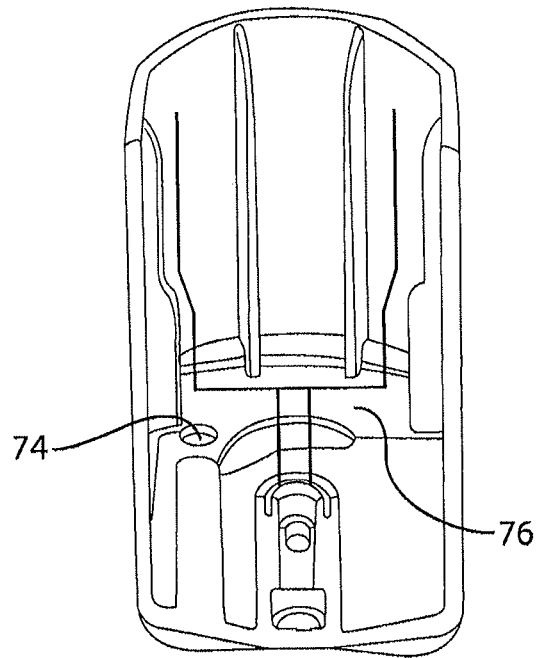


FIG. 6G





**FIG. 7A**



**FIG. 7B**

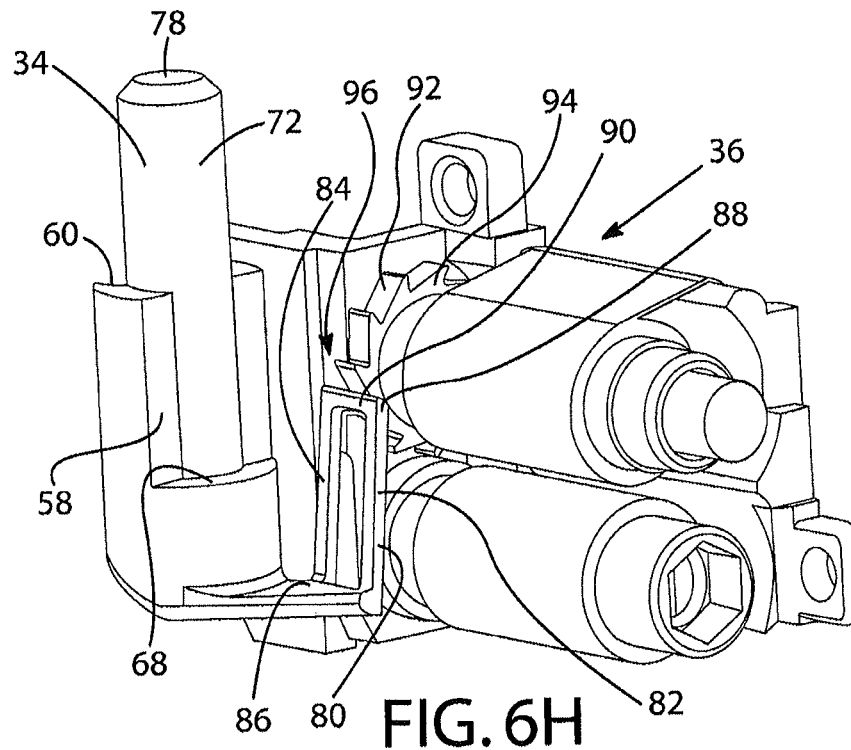


FIG. 6H

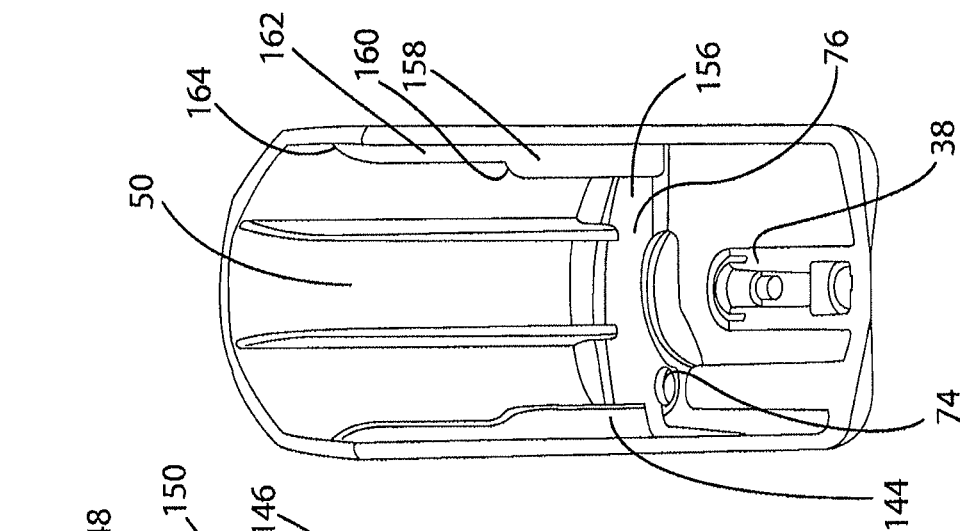


FIG. 7C

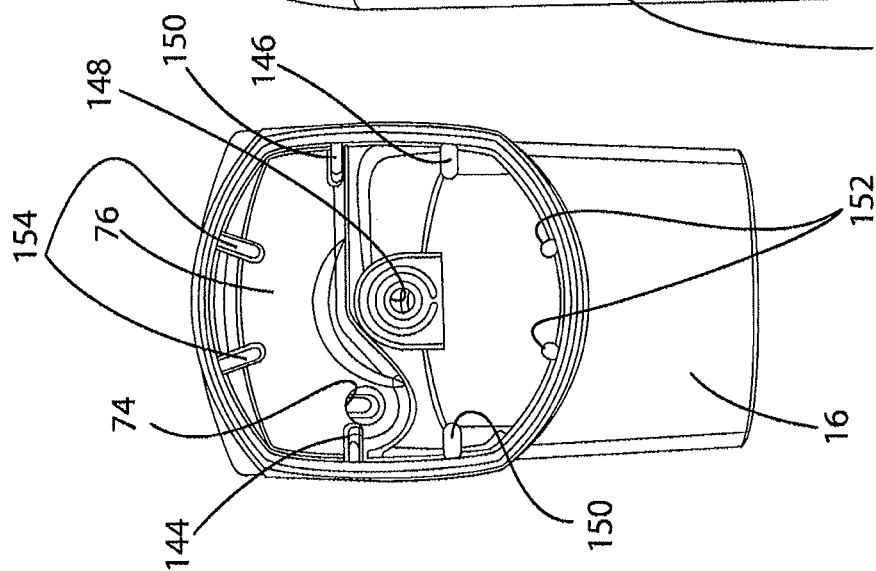


FIG. 7D

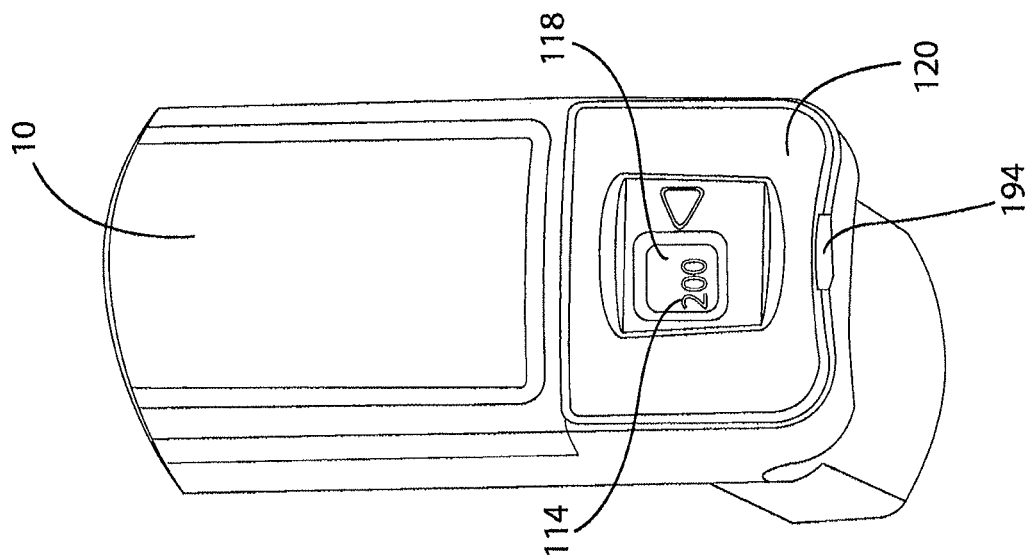


FIG. 8D

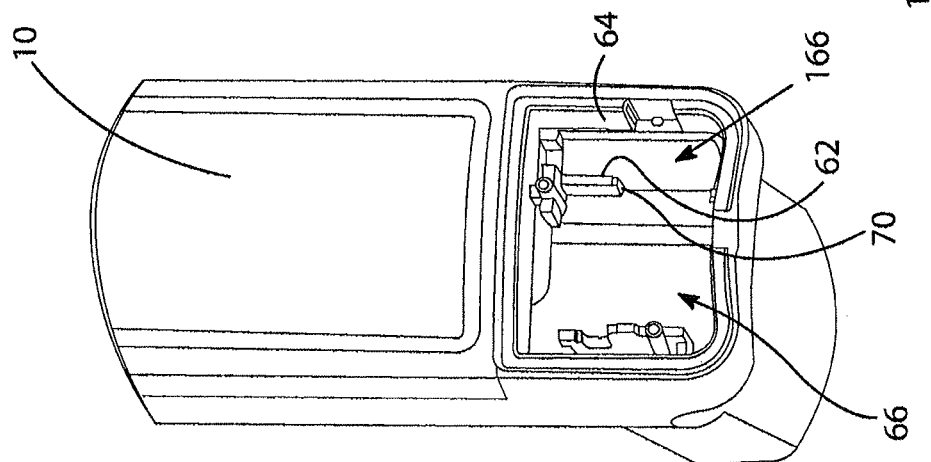


FIG. 8A

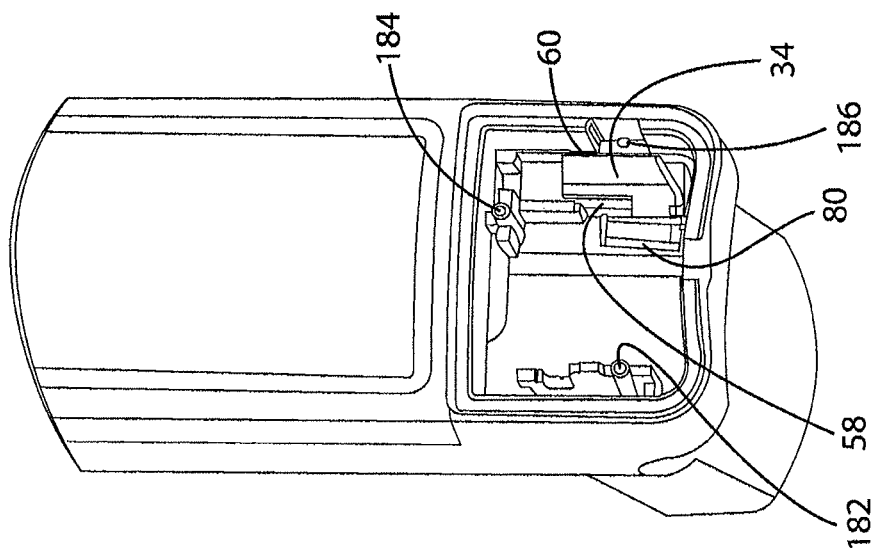


FIG. 8B

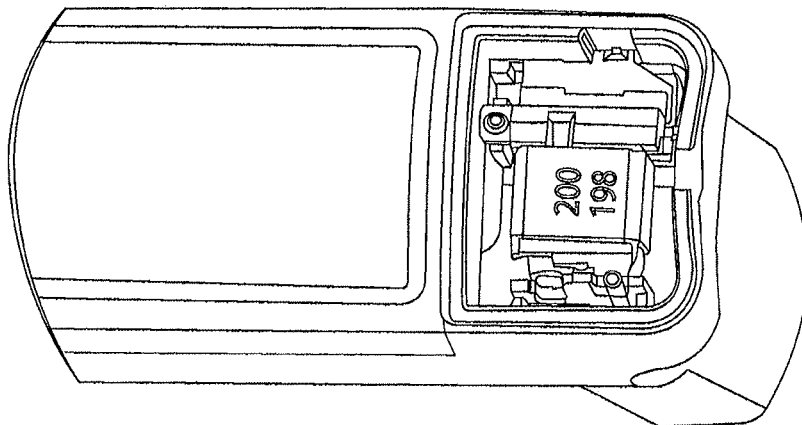


FIG. 8C

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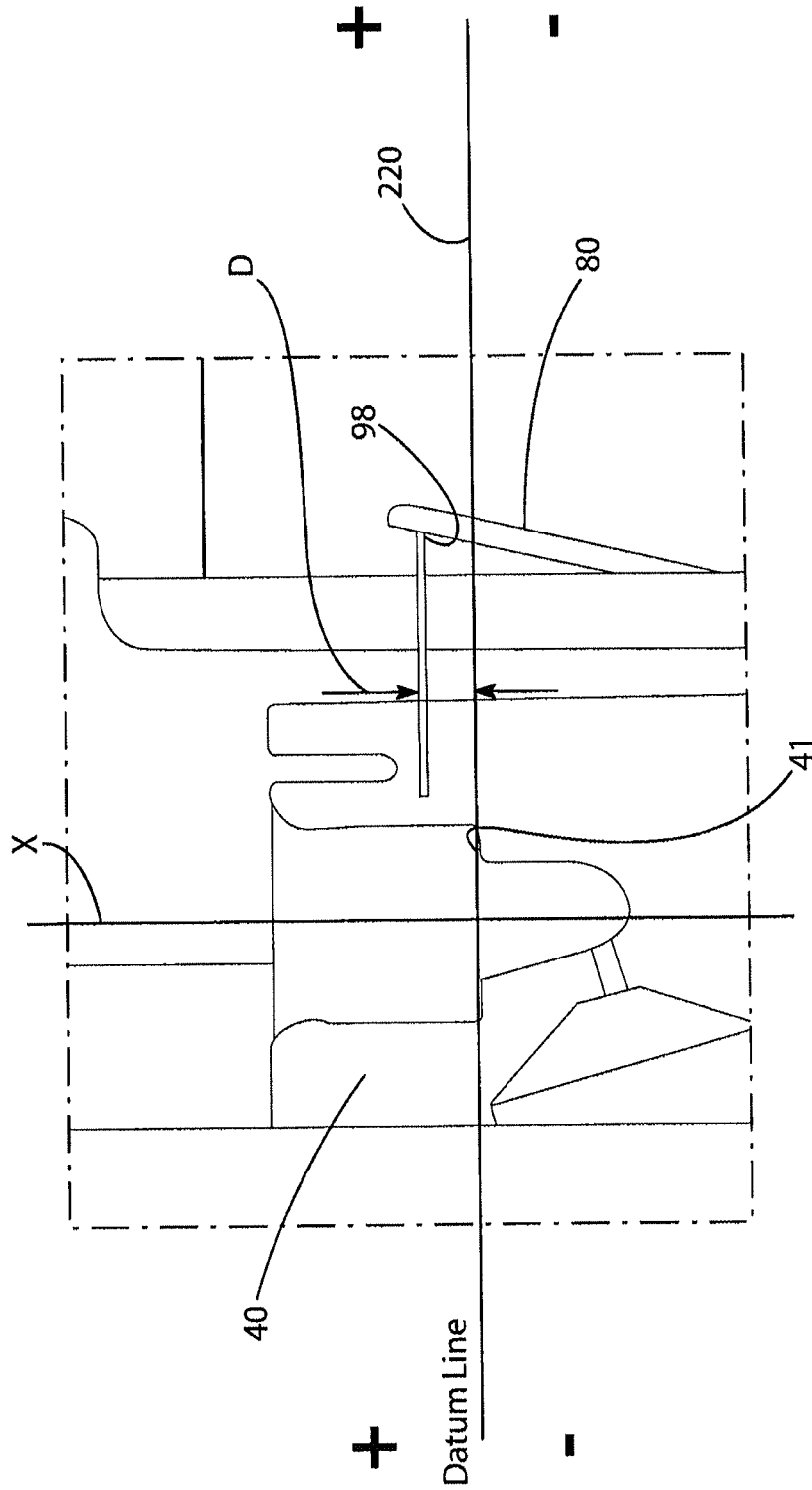


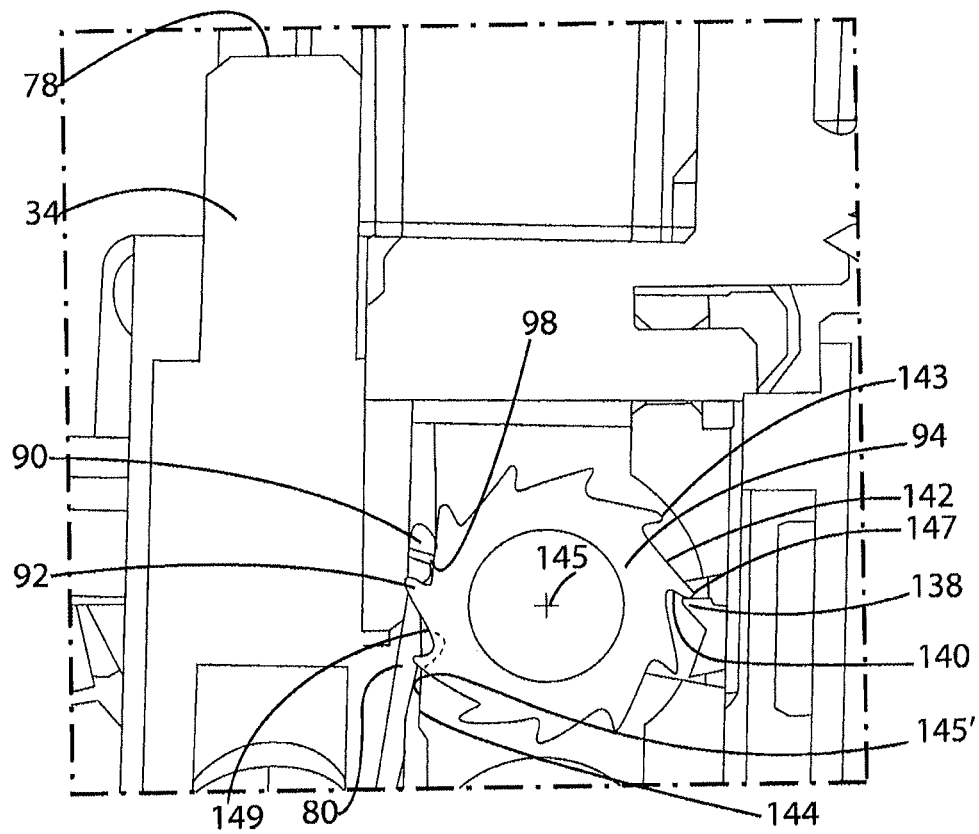
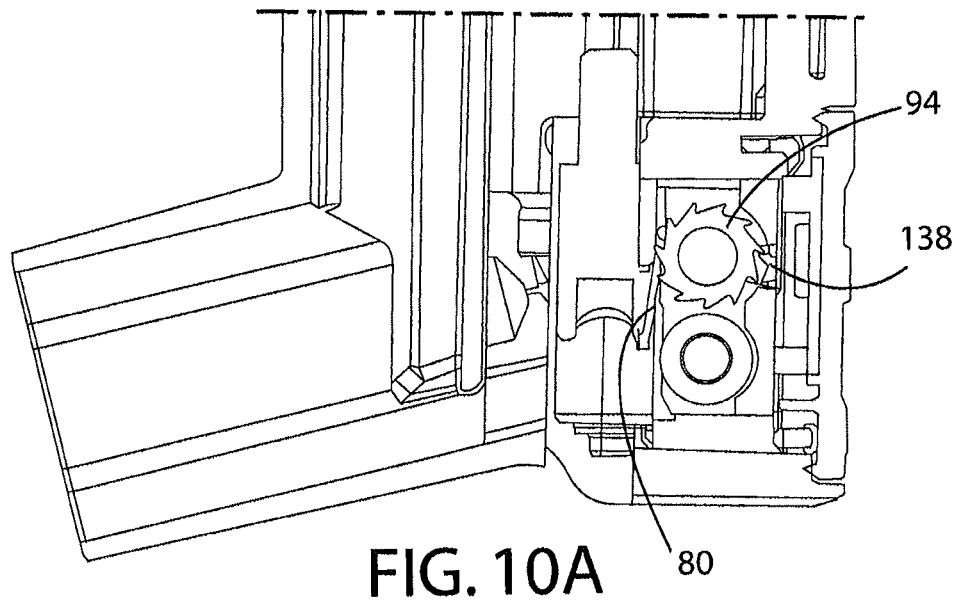
FIG. 9

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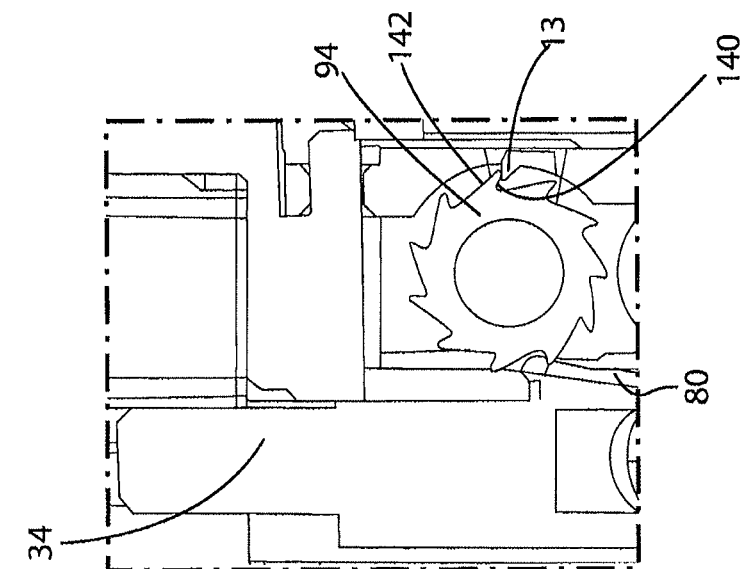


FIG. 10C

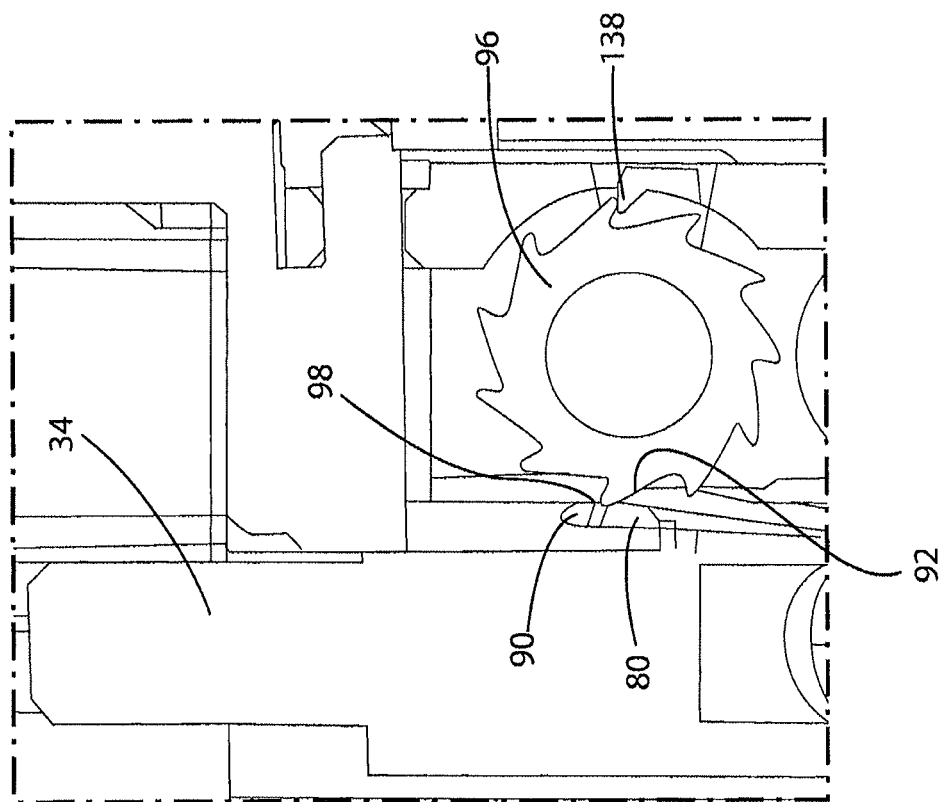


FIG. 10E



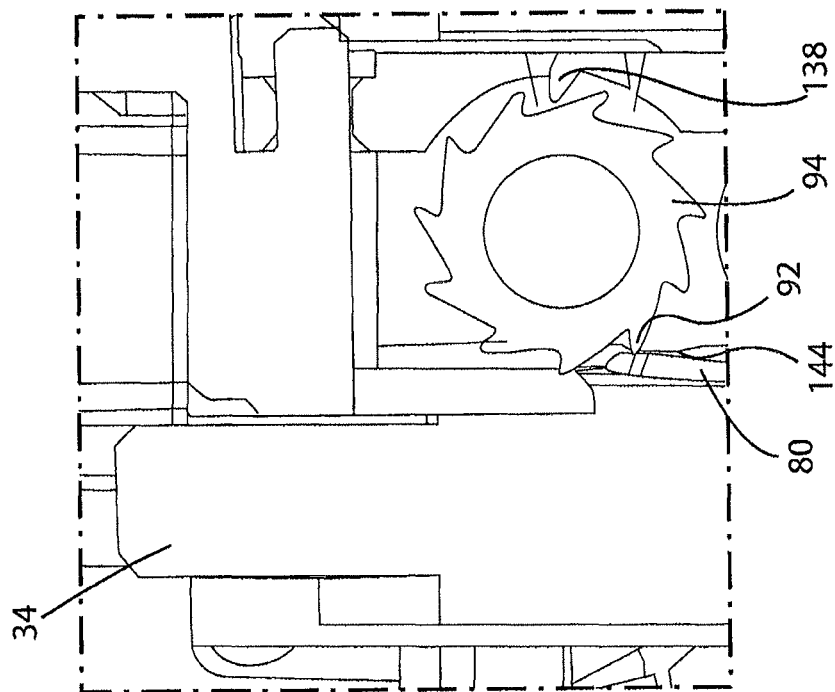


FIG. 10F

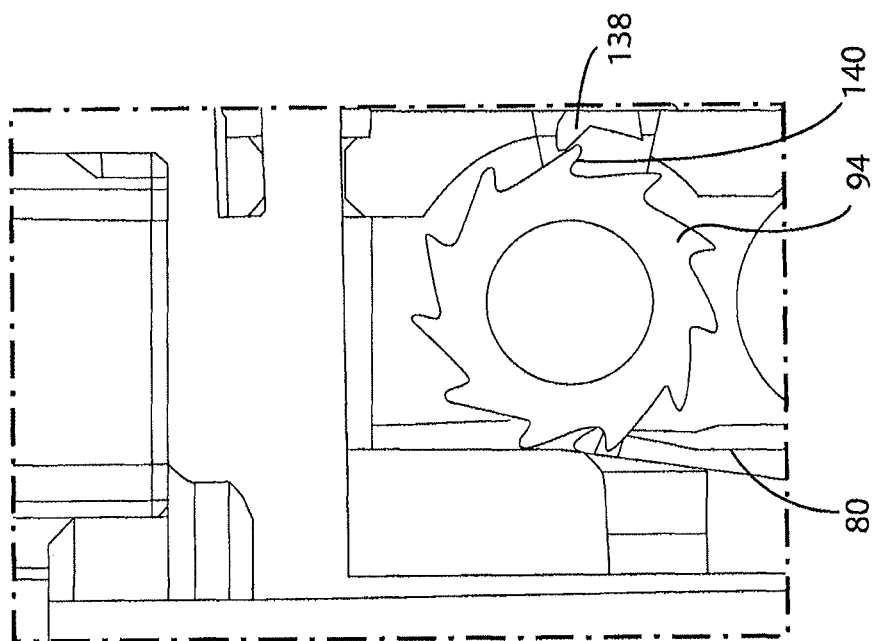


FIG. 10D

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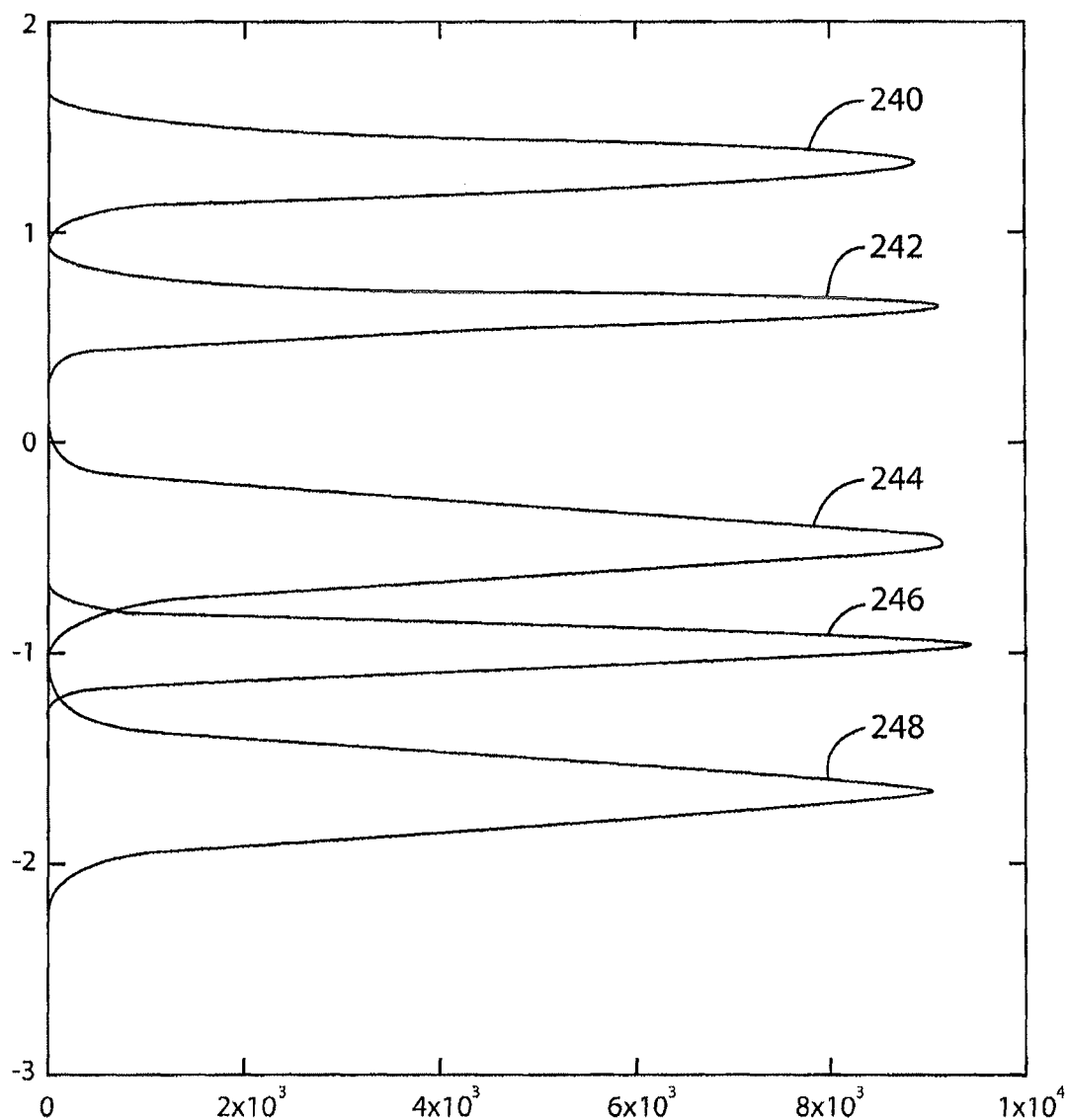


FIG. 11

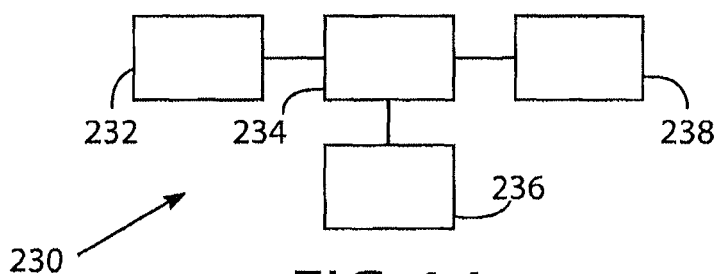


FIG. 14

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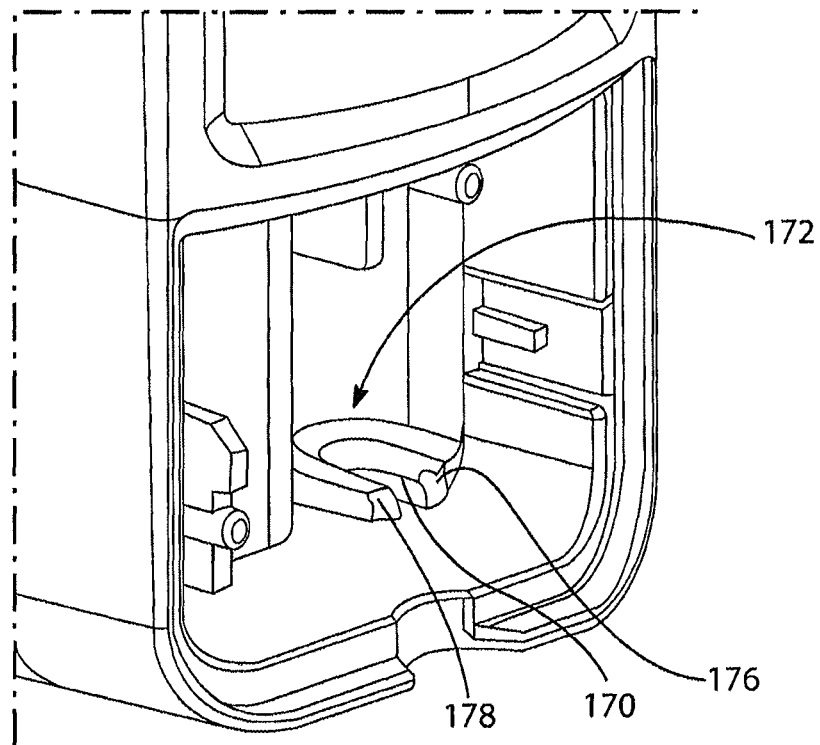


FIG. 12

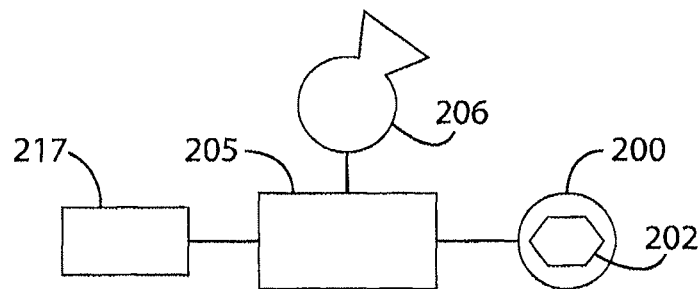
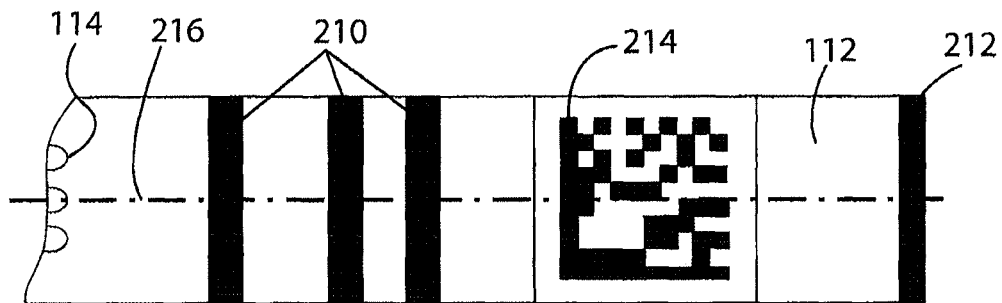


FIG. 13

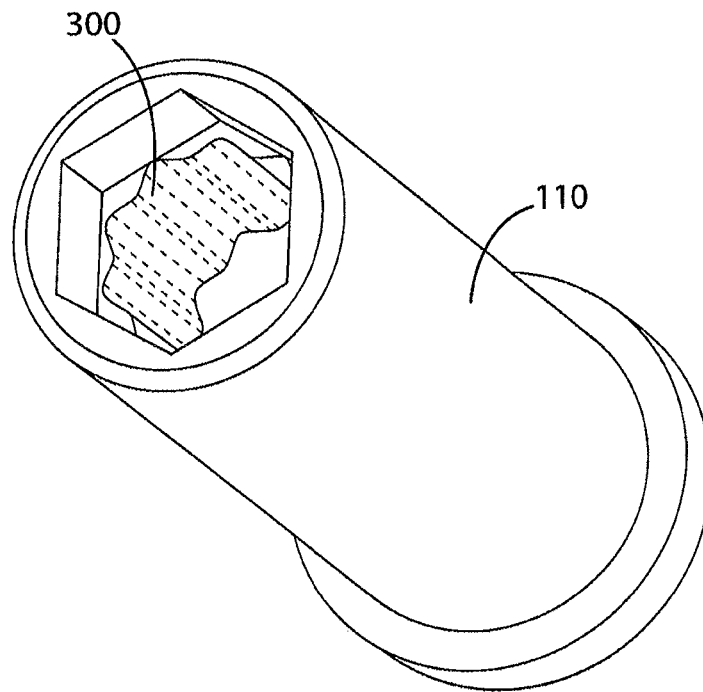


FIG. 15

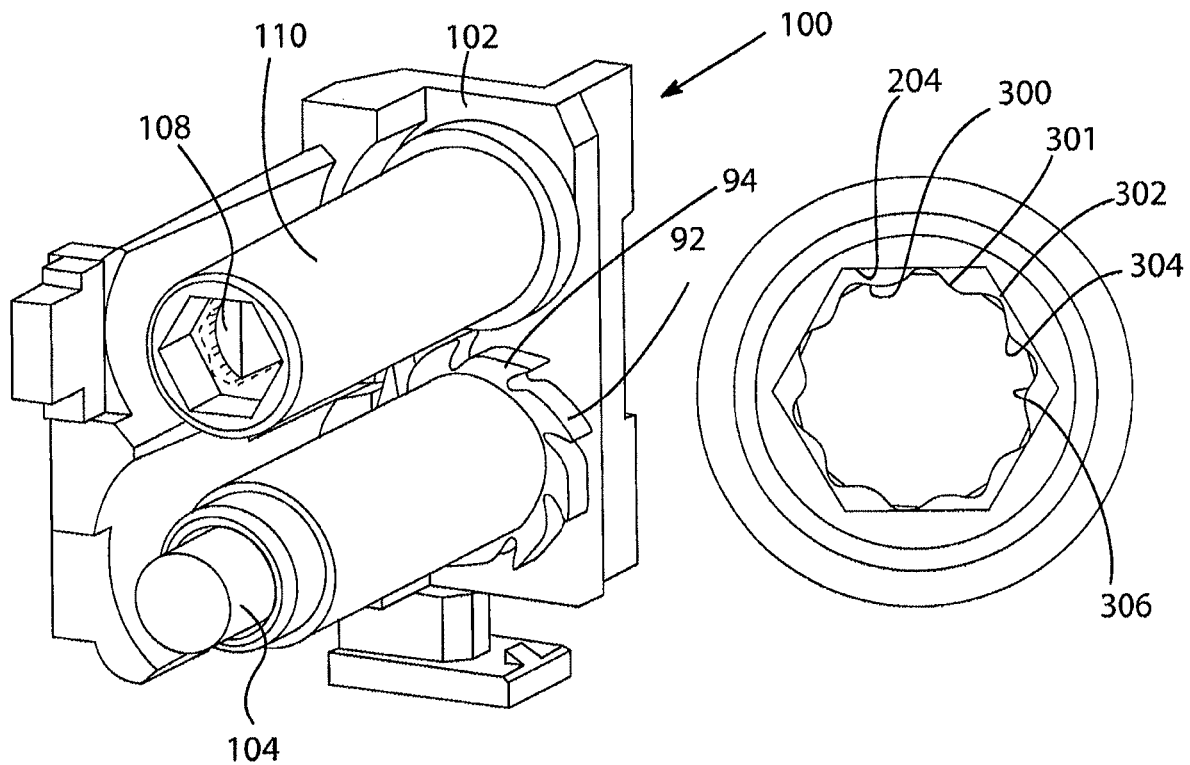


FIG. 20

FIG. 16

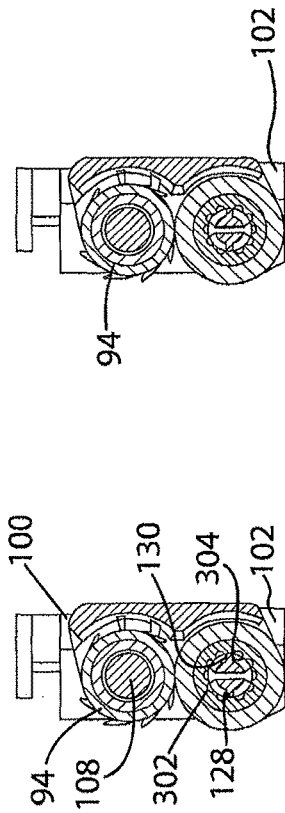


FIG. 18A

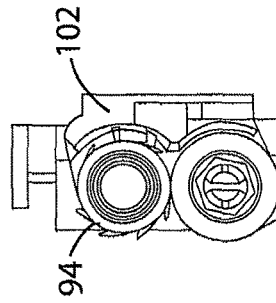


FIG. 18B

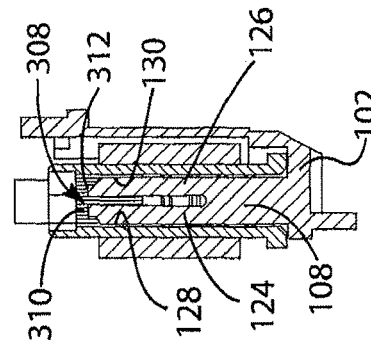


FIG. 18C

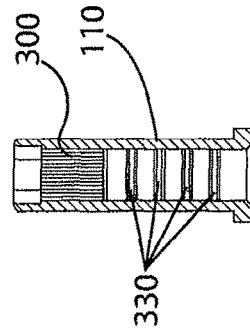


FIG. 17

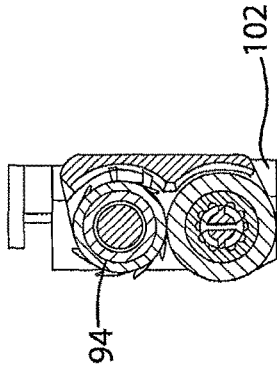


FIG. 19A

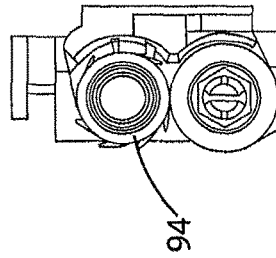


FIG. 19B

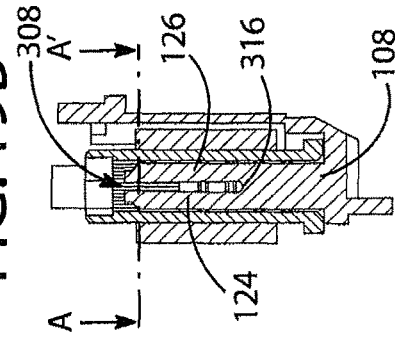


FIG. 19C

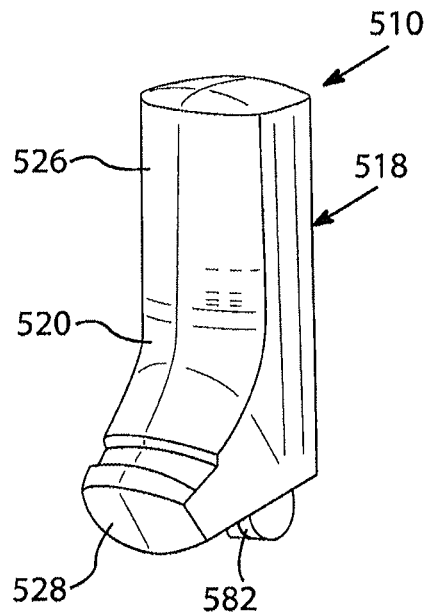


FIG. 21

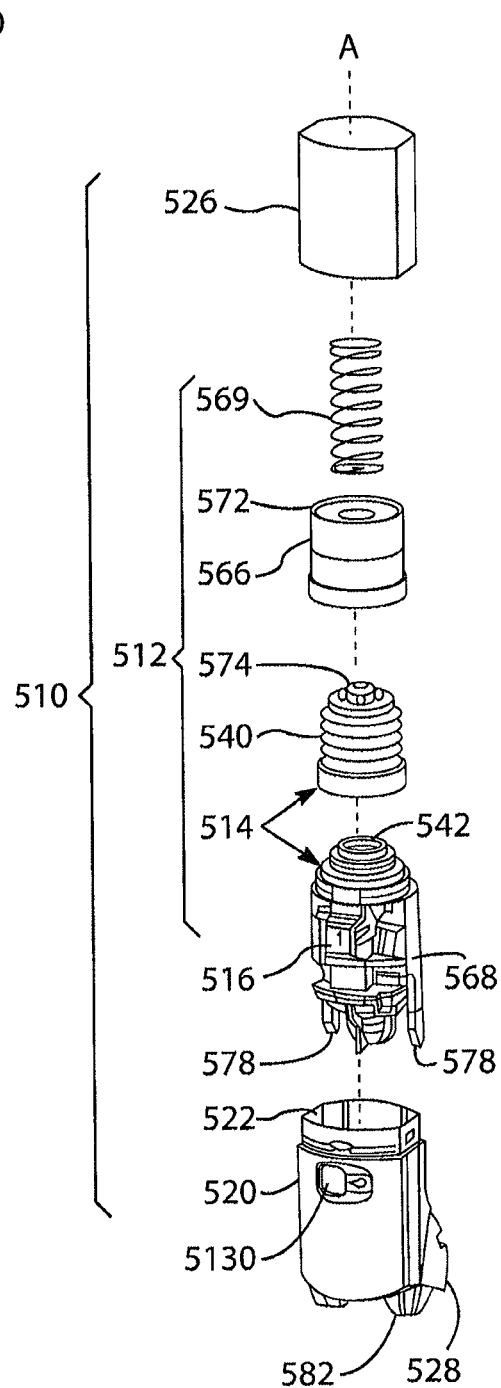


FIG. 22



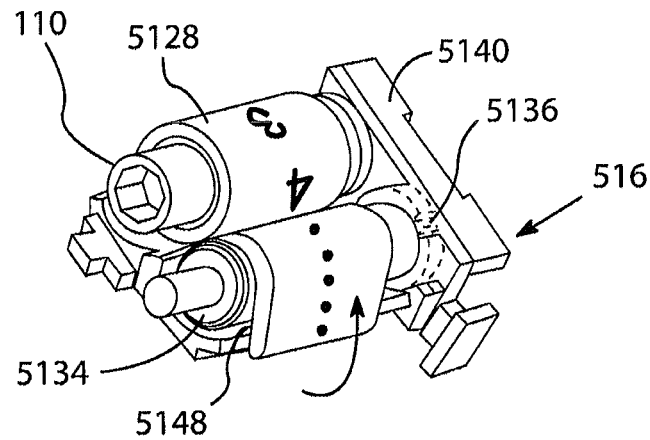


FIG. 23

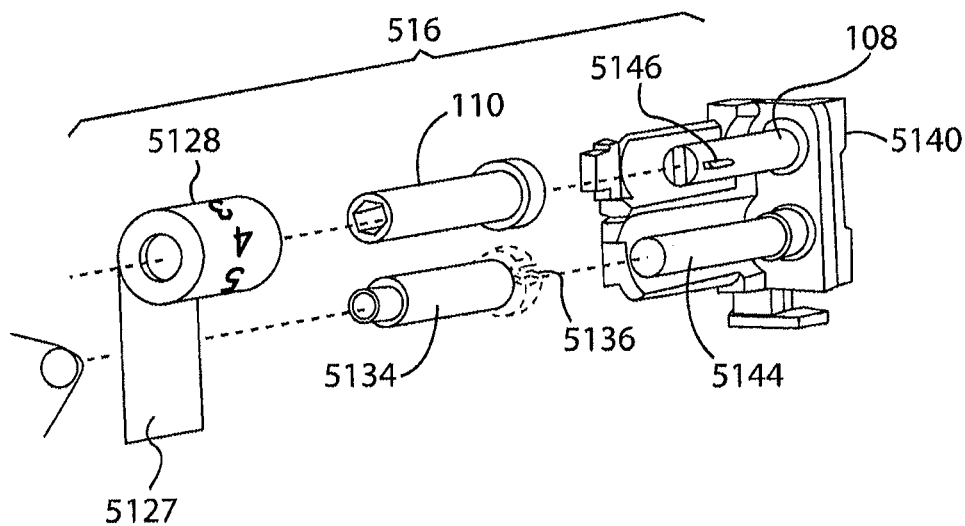


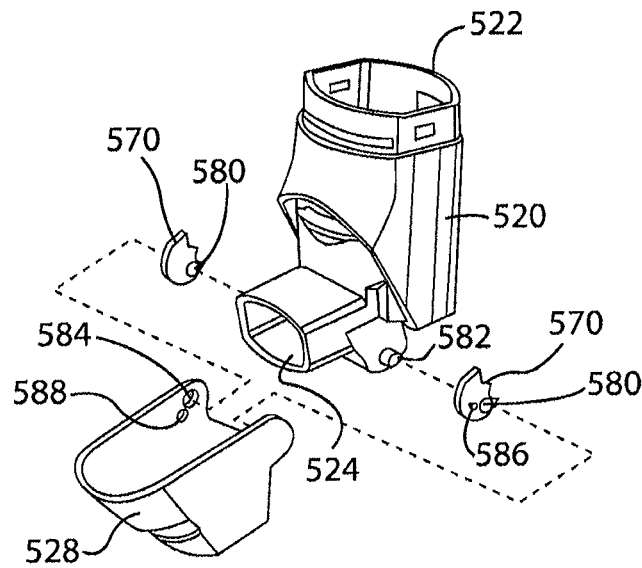
FIG. 24

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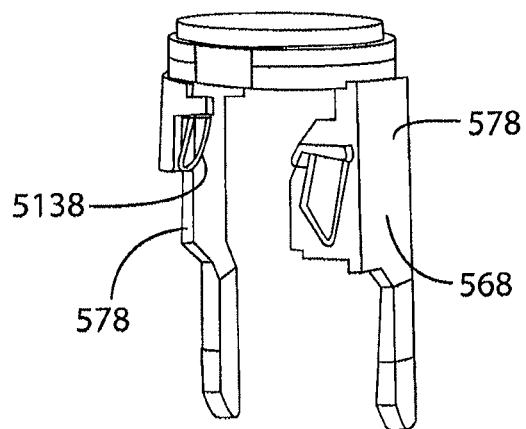
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**FIG. 25**



**FIG. 26**

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# **DOSE COUNTER FOR INHALER HAVING AN ANTI-REVERSE ROTATION ACTUATOR**

## **CROSS-REFERENCE TO RELATED APPLICATIONS**

This patent application is a continuation patent application of U.S. patent application Ser. No. 15/269,249, filed Sep. 19, 2016, now U.S. Pat. No. 9,808,587, which is a continuation of U.S. patent application Ser. No. 14/103,324, filed Dec. 11, 2013, now U.S. Pat. No. 9,463,289, which is a divisional patent application of U.S. patent application Ser. No. 13/110,532, filed May 18, 2011, now U.S. Pat. No. 8,978,966, which claims priority to U.S. patent application No. 61/345,763, filed May 18, 2010, and U.S. patent application No. 61/417,659, filed Nov. 29, 2010, each of which is incorporated herein by reference in its entirety for any and all purposes.

## **FIELD OF THE INVENTION**

The present invention relates to dose counters for inhalers, inhalers and methods of assembly thereof. The invention is particularly applicable to metered dose inhalers including dry power medicament inhalers, breath actuated inhalers and manually operated metered dose medicament inhalers.

## **BACKGROUND OF THE INVENTION**

Metered dose inhalers can comprise a medicament-containing pressurised canister containing a mixture of active drug and propellant. Such canisters are usually formed from a deep-drawn aluminium cup having a crimped lid which carries a metering valve assembly. The metering valve assembly is provided with a protruding valve stem which, in use is inserted as a push fit into a stem block in an actuator body of an inhaler having a drug delivery outlet. In order to actuate a manually operable inhaler, the user applies by hand a compressive force to a closed end of the canister and the internal components of the metering valve assembly are spring loaded so that a compressive force of approximately 15 to 30N is required to activate the device in some typical circumstances.

In response to this compressive force the canister moves axially with respect to the valve stem and the axial movement is sufficient to actuate the metering valve and cause a metered quantity of the drug and the propellant to be expelled through the valve stem. This is then released into a mouthpiece of the inhaler via a nozzle in the stem block, such that a user inhaling through the outlet of the inhaler will receive a dose of the drug.

A drawback of self-administration from an inhaler is that it is difficult to determine how much active drug and/or propellant are left in the inhaler, if any, especially of the active drug and this is potentially hazardous for the user since dosing becomes unreliable and backup devices not always available.

Inhalers incorporating dose counters have therefore become known.

WO 98/028033 discloses an inhaler having a ratchet mechanism for driving a tape drive dose counter. A shaft onto which tape is wound has a friction clutch or spring for restraining the shaft against reverse rotation.

EP-A-1486227 discloses an inhaler for dry powered medicament having a ratchet mechanism for a tape dose counter which is operated when a mouthpiece of the inhaler is closed. Due to the way in which the mouthpiece is opened

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and closed, and actuation pawl of the device which is mounted on a yoke, travels a known long stroke of consistent length as the mouthpiece is opened and closed.

WO 2008/119552 discloses a metered-dose inhaler which is suitable for breath-operated applications and operates with a known and constant canister stroke length of 3.04 mm+/-0.255 mm. A stock bobbin of the counter, from which a tape is unwound, rotates on a shaft having a split pin intended to hold the stock bobbin taut. However, some dose counters do not keep a particularly reliable count, such as if they are dropped onto a hard surface.

More recently, it has become desirable to improve dose counters further and, in particular, it is felt that it would be useful to provide extremely accurate dose counters for manually-operated canister-type metered dose inhalers. Unfortunately, in these inhalers, it has been found in the course of making the present invention that the stroke length of the canister is to a very large extent controlled on each dose operation by the user, and by hand. Therefore, the stroke length is highly variable and it is found to be extremely difficult to provide a highly reliable dose counter for these applications. The dose counter must not count a dose when the canister has not fired since this might wrongly indicate to the user that a dose has been applied and if done repeatedly the user would throw away the canister or whole device before it is really time to change the device due to the active drug and propellant reaching a set minimum. Additionally, the canister must not fire without the dose counter counting because the user may then apply another dose thinking that the canister has not fired, and if this is done repeatedly the active drug and/or propellant may run out while the user thinks the device is still suitable for use according to the counter. It has also been found to be fairly difficult to assembly some known inhaler devices and the dose counters therefor. Additionally, it is felt desirable to improve upon inhalers by making them easily usable after they have been washed with water.

The present invention aims to alleviate at least to a certain extent one or more of the problems of the prior art.

## **SUMMARY OF THE INVENTION**

According to a first aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a counter display arranged to indicate dosage information, a drive system arranged to move the counter display incrementally in a first direction from a first station to a second station in response to actuation input, wherein a regulator is provided which is arranged to act upon the counter display at the first station to regulate motion of the counter display at the first station to incremental movements.

The regulator is advantageous in that it helps prevent unwanted motion of the counter display if the counter is dropped.

According to a further aspect of the present invention, the regulator provides a resistance force of greater than 0.1 N against movement of the counter display. According to still a further aspect of the present invention, the resistance force is greater than 0.3 N. According to yet a further aspect of the present invention, the resistance force is from 0.3 to 0.4 N.

Preferably, the counter comprises a tape.

Preferably, the tape has dose counter indicia displayed thereon. The first station may comprise a region of the dose counter where tape is held which is located before a display location, such as a display window, for the counter indicia.

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The first station may comprise a first shaft, the tape being arranged on the first shaft and to unwind therefrom upon movement of the counter display.

The first shaft may be mounted for rotation relative to a substantially rotationally fixed element of the dose counter.

The regulator may comprise at least one projection which is arranged on one of the first shaft and the substantially rotationally fixed element and to engage incrementally with one or more formations on the other of the first shaft and the substantially rotationally fixed element.

At least two said projections may be provided. Exactly two said projections may be provided.

Each projection may comprise a radiused surface.

The at least one projection may be located on the substantially fixed element which may comprise a fixed shaft which is fixed to a main body of the dose counter, the first shaft being rotationally mounted to the fixed shaft.

Preferably, the fixed shaft has at least two resiliently flexible legs (or forks). Each leg may have at least one said projection formed in an outwardly facing direction thereon, said one or more formations being formed on an inwardly facing engagement surface of the first shaft, said at least one projection being arranged to resiliently engage said one or more formations. Preferably, a series of said formations are provided. An even number of said formations may be provided. Eight to twelve of said formations may be provided. In one embodiment, ten said formations are provided.

Each said formation may comprise a concavity formed on an engagement surface. Each concavity may comprise a radiused surface wall portion which preferably merges on at least one side thereof into a flat wall portion surface. The engagement surface may include a series of said concavities, and convex wall portions of the engagement surface may be formed between each adjacent two said concavities, each said convex wall portion comprising a convex radiused wall portion.

Each convex radiused wall portion of each convex wall portion may be connected by said flat wall portion surfaces to each adjacent concavity.

The fixed shaft may comprise a split pin with fork legs and each projection may be located on a said fork leg.

The first shaft may comprise a substantially hollow bobbin.

Said at least one formation may be located on an inner surface of the bobbin. In other embodiments it may be located on an outer surface thereof. Said engagement surface may extend partially along said bobbin, a remainder of the respective inner or outer surface having a generally smooth journal portion along at least a portion thereof.

The drive system may comprise a tooth ratchet wheel arranged to act upon a second shaft which is located at the second station, the second shaft being rotatable to wind the tape onto the second shaft.

The second shaft may be located on a main body of the dose counter spaced from and parallel to the first shaft.

The ratchet wheel may be fixed to the second shaft is arranged to rotate therewith. The ratchet wheel may be secured to an end of the second shaft and aligned coaxially with the second shaft.

The dose counter may include anti-back drive system which is arranged to restrict motion of the second shaft. The anti-back drive system may include a substantially fixed tooth arranged to act upon teeth of the ratchet wheel.

According to a further aspect of the present invention, a dose counter includes an anti-back drive system which is arranged to restrict motion of the second shaft in a tape winding direction.

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According to a further aspect of the present invention there is provided a shaft for holding counter tape in a dose counter for an inhaler, the shaft having an engagement surface including incrementally spaced formations located around a periphery thereof, the formations comprising a series of curved concavities and convex portions.

The shaft may comprise a hollow bobbin.

The engagement surface may be a generally cylindrical inwardly directed surface.

The engagement surface may include a flat surface wall portion joining each concavity and convex wall portion.

Each concavity may comprise a radiused wall portion.

Each convex wall portion may comprise a radiused wall portion.

Said concavities may be regularly spaced around a longitudinal axis of the shaft.

Said convex wall portions may be regularly spaced around a longitudinal axis of the shaft.

In some embodiments there may be from eight to twelve said concavities and/or convex wall portions regularly spaced around a longitudinal axis thereof.

One embodiment includes ten said concavities and/or convex wall portions regularly spaced around a longitudinal axis of the shaft.

According to a further aspect of the present invention there is provided a shaft and counter tape assembly for use in a dose counter for an inhaler, the assembly comprising a rotatable shaft and a counter tape which is wound around the shaft and is adapted to unwind therefrom upon inhaler actuation, the shaft having an engagement surface which includes incrementally spaced formations located around a periphery thereof.

According to a further aspect of the present invention there is provided an inhaler for the inhalation of medication and the like, the inhaler including a dose counter as in the first aspect of the present invention.

A preferred construction consists of a manually operated metered dose inhaler including a dose counter chamber including a dose display tape driven by a ratchet wheel which is driven in turn by an actuator pawl actuated by movement of a canister, the tape unwinding from a stock bobbin during use of the inhaler, a rotation regulator being provided for the stock bobbin and comprising a wavelike engagement surface with concavities which engage against control elements in the form of protrusions on resilient forks of a split pin thereby permitting incremental unwinding of the stock bobbin yet resisting excessive rotation if the inhaler is dropped onto a hard surface.

According to another aspect of the present invention there is provided a dose counter for a metered dose inhaler having a body arranged to retain a medicament canister of predetermined configuration for movement of the canister relative thereto; the dose counter comprising: an incremental counting system for counting doses, the incremental counting system having a main body, an actuator arranged to be driven in response to canister motion and to drive an incremental output member in response to canister motion, the actuator and incremental output member being configured to have predetermined canister fire and count configurations in a canister fire sequence, the canister fire configuration being determined by a position of the actuator relative to a datum at which the canister fires medicament and the count configuration being determined by a position of the actuator relative to the datum at which the incremental count system makes an incremental count, wherein the actuator is

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arranged to reach a position thereof in the count configuration at or after a position thereof in the canister fire configuration.

This arrangement has been found to be highly advantageous since it provides an extremely accurate dose counter which is suitable for use with manually operated metered dose inhalers. It has been found that dose counters with these features have a failure rate of less than 50 failed counts per million full canister activation depressions. It has been found in the course of making the present invention that highly reliable counting can be achieved with the dose counter counting at or soon after the point at which the canister fires. It has been is covered by the present inventors that momentum and motion involved in firing the canister, and in some embodiments a slight reduction in canister back pressure on the user at the time of canister firing, can very reliably result in additional further motion past the count point.

The actuator and incremental counting system may be arranged such that the actuator is displaced less than 1 mm, typically 0.25 to 0.75 mm, more preferably about 0.4 to 0.6 mm, relative to the body between its location in the count and fire configurations, about 0.48 mm being preferred. The canister, which can move substantially in line with the actuator, can reliably move this additional distance so as to achieve very reliable counting.

The incremental count system may comprise a ratchet mechanism and the incremental output member may comprise a ratchet wheel having a plurality of circumferentially spaced teeth arranged to engage the actuator.

The actuator may comprise an actuator pawl arranged to engage on teeth of the ratchet wheel. The actuator pawl may be arranged to be connected to or integral with an actuator pin arranged to engage and be depressed by a medicament canister bottom flange. The actuator pawl may be generally U-shaped having two parallel arms arranged to pull on a central pawl member arranged substantially perpendicular thereto. This provides a very reliable actuator pawl which can reliably pull on the teeth of the ratchet wheel.

The incremental count system may include a tape counter having tape with incremental dose indicia located thereon, the tape being positioned on a tape stock bobbin and being arranged to unwind therefrom.

The actuator and incremental output member may be arranged to provide a start configuration at which the actuator is spaced from the ratchet output member, a reset configuration at which the actuator is brought into engagement with the incremental output member during a canister fire sequence, and an end configuration at which the actuator disengages from the ratchet output during a canister fire sequence.

The actuator may be arranged to be located about 1.5 to 2.0 mm, from its location in the fire configuration, when in the start configuration, about 1.80 mm being preferred.

The actuator may be arranged to be located about 1.0 to 1.2 mm, from its location in the fire configuration, when in the reset configuration, about 1.11 mm being preferred.

The actuator may be arranged to be located about 1.1 to 1.3 mm, from its location in the fire configuration, when in the end configuration, about 1.18 mm being preferred.

These arrangements provide extremely reliable dose counting, especially with manually operated canister type metered dose inhalers.

The main body may include a formation for forcing the actuator to disengage from the incremental output member when the actuator is moved past the end configuration. The formation may comprise a bumped up portion of an other-

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wise generally straight surface against which the actuator engages and along which it is arranged to slide during a canister firing sequence.

The dose counter may include a counter pawl, the counter pawl having a tooth arranged to engage the incremental output member, the tooth and incremental output member being arranged to permit one way only incremental relative motion therebetween. When the incremental output member comprises a ratchet wheel, the tooth can therefore serve as an anti-back drive tooth for the ratchet wheel, thereby permitting only one way motion or rotation thereof.

The counter pawl may be substantially fixedly mounted on the main body of the incremental count system and the counter pawl may be arranged to be capable of repeatedly engaging equi-spaced teeth of the incremental output member in anti-back drive interlock configurations as the counter is operated. The counter pawl may be positioned so that the incremental output member is halfway, or substantially halfway moved from one anti-back drive interlock configuration to the next when the actuator and incremental output member are in the end configuration thereof. This is highly advantageous in that it minimises the risk of double counting or non-counting by the dose counter.

According to a further aspect of the invention there is provided an inhaler comprising a main body arranged to retain a medicament canister of predetermined configuration and a dose counter mounted in the main body.

The inhaler main body may include a canister receiving portion and a separate counter chamber, the dose counter being located within the main body thereof, the incremental output member and actuator thereof inside the counter chamber, the main body of the inhaler having wall surfaces separating the canister-receiving portion and the counter chamber, the wall surfaces being provided with a communication aperture, an actuation member extending through the communication aperture to transmit canister motion to the actuator.

According to a further aspect of the present invention there is a provided an inhaler for metered dose inhalation, the inhaler comprising a main body having a canister housing arranged to retain a medicament canister for motion therein, and a dose counter, the dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of a medicament canister, wherein the canister housing has an inner wall, and a first inner wall canister support formation located directly adjacent the actuation member.

This is highly advantageous in that the first inner wall canister support formation can prevent a canister from rocking too much relative to the main body of the inhaler. Since the canister may operate the actuation member of the dose counter, this substantially improves dose counting and avoids counter errors.

The canister housing may have a longitudinal axis which passes through a central outlet port thereof, the central outlet port being arranged to mate with an outer canister fire stem of a medicament canister, the inner wall canister support formation, the actuation member and the outlet port lying in a common plane coincident with the longitudinal axis. Accordingly, this construction may prevent the canister from rocking towards the position of the dose counter actuation member, thereby minimising errors in counting.

The canister housing may have a further inner canister wall support formation located on the inner wall opposite, or substantially opposite, the actuation member. Accordingly, the canister may be supported against rocking motion away from the actuator member so as to minimise count errors.



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The canister housing may be generally straight and tubular and may have an arrangement in which each said inner wall support formation comprises a rail extending longitudinally along the inner wall.

Each said rail may be stepped, in that it may have a first portion located towards a medicine outlet end or stem block of the canister housing which extends inwardly a first distance from a main surface of the inner wall and a second portion located toward an opposite end of the canister chamber which extends inwardly a second, smaller distance from the main surface of the inner wall. This may therefore enable easy insertion of a canister into the canister housing such that a canister can be lined up gradually in step wise function as it is inserted into the canister housing.

The inhaler may include additional canister support rails which are spaced around an inner periphery of the inner wall of the canister housing and which extend longitudinally therealong.

At least one of the additional rails may extend a constant distance inwardly from the main surface of the inner wall.

At least one of the additional rails may be formed with a similar configuration to the first inner wall canister support formation.

The dose counter may, apart from said at least a portion of the actuation member, be located in a counter chamber separate from the canister housing, the actuation member comprising a pin extending through an aperture in a wall which separates the counter chamber and the canister housing.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicaments having: a body for retaining a medicament store; the body including a dose counter, the dose counter having a moveable actuator and a return spring for the actuator, the return spring having a generally cylindrical and annular end; the body having a support formation therein for supporting said end of the return spring, the support formation comprising a shelf onto which said end is engageable and a recess below the shelf.

This shelf and recess arrangement is highly advantageous since it allows a tool (such as manual or mechanical tweezers) to be used to place the return spring of the actuator onto the shelf with the tool then being withdrawn at least partially via the recess.

The shelf may be U-shaped.

The support formation may include a U-shaped upstanding wall extending around the U-shaped shelf, the shelf and upstanding wall thereby forming a step and riser of a stepped arrangement.

The recess below the shelf may also be U-shaped.

At least one chamfered surface may be provided at an entrance to the shelf. This may assist in inserting the actuator and return spring into position.

A further aspect of the invention provides a method of assembly of an inhaler which includes the step of locating said end of said spring on the shelf with an assembly tool and then withdrawing the assembly tool at least partly via the recess. This assembly method is highly advantageous compared to prior art methods in which spring insertion has been difficult and in which withdrawal of the tool has sometimes accidentally withdrawn the spring again.

The cylindrical and annular end of the spring may be movable in a direction transverse to its cylindrical extent into the shelf while being located thereon.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament, the inhaler having a body for retaining a medicament store; and

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a dose counter, the dose counter having a moveable actuator and a chassis mounted on the body; the chassis being heat staked in position on the body. This is highly advantageous in that the chassis can be very accurately positioned and held firmly in place, thereby further improving counting accuracy compared to prior art arrangements in which some movement of the chassis relative to the body may be tolerated in snap-fit connections.

The chassis may have at least one of a pin or aperture heat staked to a respective aperture or pin of the body.

The chassis may have a ratchet counter output member mounted thereon.

The ratchet counter output member may comprise a ratchet wheel arranged to reel in incrementally a dose meter tape having a dosage indicia located thereon.

According to a further aspect of the present invention there is provided a method of assembling an inhaler including the step of heat staking the chassis onto the body. The step of heat staking is highly advantageous in fixedly positioning the chassis onto the body in order to achieve highly accurate dose counting in the assembled inhaler.

The method of assembly may include mounting a spring-returned ratchet actuator in the body before heat staking the chassis in place. The method of assembly may include pre-assembling the chassis with a dose meter tape prior to the step of heat staking the chassis in place. The method of assembly may include attaching a dose meter cover onto the body after the heat staking step. The cover may be welded onto the body or may in some embodiments be glued or otherwise attached in place.

According to a further aspect of the present invention there is provided an inhaler for inhaling medicament and having a body, the body have a main part thereof for retaining a medicament store; and a dose counter, the dose counter being located in a dose counter chamber of the body which is separated from the main part of the body, the dose counter chamber of the body having a dosage display and being perforated so as to permit the evaporation of water or aqueous matter in the dose counter chamber into the atmosphere.

This is high advantageous since it enables the inhaler to be thoroughly washed and the dose counting chamber can thereafter dry out fully.

The display may comprise a mechanical counter display inside the dose counter chamber and a window for viewing the mechanical counter display. The mechanical counter display may comprise a tape. The perforated dose counter chamber may therefore enable reliable washing of the inhaler, if desired by the user, and may therefore dry out without the display window misting up.

The dose counter chamber may be perforated by a drain hole formed through an outer hole of the body. The drain hole may be located at a bottom portion of the body of the inhaler, thereby enabling full draining of the inhaler to be encouraged after washing when the inhaler is brought into an upright position.

According to a further aspect of the present invention there is provided a dose counter for an inhaler, the dose counter having a display tape arranged to be incrementally driven from a tape stock bobbin onto an incremental tape take-up drive shaft, the bobbin having an internal bore supported by and for rotation about a support shaft, at least one of the bore and support shaft having a protrusion which is resiliently biased into frictional engagement with the other of the bore and support shaft with longitudinally extending mutual frictional interaction. This arrangement may provide good friction for the bobbin, thereby improving tape counter



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display accuracy and preventing the bobbin from unwinding undesirably for example if the inhaler is accidentally dropped.

The support shaft may be forked and resilient for resiliently biasing the support shaft and bore into frictional engagement.

The support shaft may have two forks, or more in some cases, each having a radially extending protrusion having a friction edge extending therealong parallel to a longitudinal axis of the support shaft for frictionally engaging the bore of the support shaft with longitudinally extending frictional interaction therebetween.

The bore may be a smooth circularly cylindrical or substantially cylindrical bore.

Each of the above inhalers in accordance with aspects of the present invention may have a medicament canister mounted thereto.

The canister may comprise a pressurised metered dose canister having a reciprocally movable stem extending therefrom and movable into a main canister portion thereof for releasing a metered dose of medicament under pressure, for example by operating a metered dose valve inside the canister body. The canister may be operable by pressing by hand on the main canister body.

In cases in which one or more support rails or inner wall support formations are provided, the canister may at all times when within the canister chamber have a clearance of about 0.25 to 0.35 mm from the first inner wall support formation. The clearance may be almost exactly 0.3 mm. This clearance which may apply to the canister body itself or to the canister once a label has been applied, is enough to allow smooth motion of the canister in the inhaler while at the same time preventing substantial rocking of the canister which could result in inaccurate counting by a dose counter of the inhaler, especially when lower face of the canister is arranged to engage an actuator member of the dose counter for counting purposes.

According to a further aspect of the invention, a method of assembling a dose counter for an inhaler comprises the steps of providing a tape with dosing indicia thereon; providing tape positioning indicia on the tape; and stowing the tape while monitoring for the tape positioning indicia with a sensor. The method advantageously permits efficient and accurate stowing of the tape, e.g. by winding.

The dosing indicia may be provided as numbers, the tape positioning indicia may be provided as one or more lines across the tape. The stowing step comprises winding the tape onto a bobbin or shaft, and, optionally, stopping winding when the positioning indicia are in a predetermined position. The tape may be provided with pixelated indicia at a position spaced along the tape from the positioning indicia. The tape may also be provided with a priming dot.

According to a further aspect of the invention, a tape system for a dose counter for an inhaler has a main elongate tape structure, and dosing indicia and tape positioning indicia located on the tape structure. The tape positioning indicia may comprise at least one line extending across the tape structure. The tape system may comprise pixelated indicia located on the tape structure and spaced from the positioning indicia. The tape system may comprise a priming dot located on the tape structure. The positioning indicia may be located between the timing dot and the pixelated indicia. The main elongate tape structure may have at least one end thereof wound on a bobbin or shaft.

A further aspect of the invention provides a method of designing an incremental dose counter for an inhaler comprising the steps of calculating nominal canister fire and

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dose counter positions for a dose counter actuator of the inhaler; calculating a failure/success rate for dose counters built to tolerance levels for counting each fire of inhalers in which the dose counter actuators may be applied; and selecting a tolerance level to result in said failure/success rate to be at or below/above a predetermined value. This is highly advantageous in that it allows an efficient and accurate prediction of the reliability of a series of inhaler counters made in accordance with the design.

The method of designing may include selecting the failure/success rate as a failure rate of no more than one in 50 million. The method of designing may include setting an average count position for dose counters built to the tolerances to be at or after an average fire position thereof during canister firing motion. The method of designing may include setting the average count position to be about 0.4 to 0.6 mm after the average fire position, such as about 0.48 mm after. The method of designing may include setting tolerances for the standard deviation of the fire position in dose counters built to the tolerances to be about 0.12 to 0.16 mm, such as about 0.141 mm. The method of designing may include setting tolerances for the standard deviation of the count positions in dose counters built to the tolerances to be about 0.07 to 0.09 mm, such as about 0.08 mm. A further aspect of the invention provides a computer implemented method of designing an incremental dose counter for an inhaler which includes the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing in a production run a series of incremental dose counters for inhalers which comprises manufacturing the series of dose counters in accordance with the aforementioned method of designing.

A further aspect of the invention provides a method of manufacturing a series of incremental dose counters for inhalers, which comprises manufacturing the dose counters with nominal canister fire and dose count positions of a dose counter actuator relative to a dose counter chassis (or inhaler main body), and which includes building the dose counters with the average dose count position in the series being, in canister fire process, at or after the average canister fire position in the series.

According to a further aspect of the invention, the method provides fitting each dose counter in the series of incremental dose counters to a corresponding main body of an inhaler.

These aspects advantageously provide for the production run of a series of inhalers and dose counters which count reliably in operation.

According to a further aspect of the invention, an incremental dose counter for a metered dose inhaler has a body arranged to retain a canister for movement of the canister relative thereto, the incremental dose counter having a main body, an actuator arranged to be driven and to drive an incremental output member in a count direction in response to canister motion, the actuator being configured to restrict motion of the output member in a direction opposite to the count direction. This advantageously enables an inhaler dose counter to keep a reliable count of remaining doses even if dropped or otherwise jolted.

The output member may comprise a ratchet wheel. The actuator may comprise a pawl and in which the ratchet wheel and pawl are arranged to permit only one-way ratcheting motion of the wheel relative to the pawl. The dose counter may include an anti-back drive member fixed to the main body. In a rest position of the dose counter, the ratchet wheel is capable of adopting a configuration in which a back surface of one tooth thereof engages the anti-back drive member and the pawl is spaced from an adjacent back

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surface of another tooth of the ratchet wheel without positive drive/blocking engagement between the pawl and wheel.

# BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may be carried out in various ways and preferred embodiment of a dose counter, inhaler and methods of assembly, design and manufacture will now be described with reference to the accompanying drawings in which:

FIG. 1 is an isometric view of a main body of an embodiment of an inhaler related to the invention together with a mouthpiece cap therefor;

FIG. 2 is a top plan view of the components as shown in FIG. 1;

FIG. 3A is a section on the plane 3A-3A in FIG. 2;

FIG. 3B is a view corresponding to FIG. 3A but with a dose counter fitted to the main body of the inhaler;

FIG. 4A is an exploded view of the inhaler main body, mouthpiece cap, dose counter and a dose counter window;

FIG. 4B is a view in the direction 4B in FIG. 4C of a spring retainer of the dose counter;

FIG. 4C is a top view of the spring retainer of FIG. 4B;

FIG. 5 is a bottom view of the assembled inhaler main body, mouthpiece cap, dose counter and dose counter window;

FIGS. 6A, 6B, 6C, 6D, 6E, 6F, 6G and 6H are various views of dose counter components of the inhaler;

FIGS. 7A and 7B are sectional views showing canister clearance inside the main body of the inhaler;

FIG. 7C is a further sectional view similar to that of FIG. 7B but with the canister removed;

FIG. 7D is a top plan view of the inhaler main body;

FIGS. 8A, 8B, 8C and 8D show the inhaler main body and dose counter components during assembly thereof;

FIG. 9 shows a sectional side view of a datum line for an actuator pawl of the dose counter;

FIGS. 10A, 10B, 10C, 10D, 10E and 10F show various side views of positions and configurations of the actuator pawl, a ratchet wheel, and a count pawl;

FIG. 11 shows distributions for tolerances of start, reset, fire, count and end positions for the actuator of the dose counter;

FIG. 12 is an enlarged version of part of FIG. 4A;

FIG. 13 shows an end portion of a tape of the dose counter;

FIG. 14 shows a computer system for designing the dose counter;

FIG. 15 is an isometric view of a stock bobbin modified in accordance with the present invention for use in the dose counter of the inhaler of FIGS. 1 to 14;

FIG. 16 shows an end view of the stock bobbin of FIG. 15;

FIG. 17 is a section through a longitudinal axis of the stock bobbin of FIGS. 15 and 16;

FIGS. 18A, 18B and 18C are views of the stock bobbin of FIGS. 15 to 17 mounted in the dose counter chassis of FIGS. 1 to 14, with the control elements of the forks of the second shaft (or split pin) having a profile slightly different to that in FIG. 6F, with the forks in a compressed configuration;

FIGS. 19A, 19B and 19C are views equivalent to FIGS. 18A to 18C but with the forks in a more expanded configuration due to a different rotational position of the stock bobbin;

FIG. 20 is an isometric view of the chassis assembled and including the stock bobbin of FIGS. 15 to 17 but excluding the tape for reasons of clarity;

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FIG. 21 is a view of a preferred embodiment of a dry powder inhaler in accordance with the present invention;

FIG. 22 is an exploded view of the inhaler of FIG. 21;

FIG. 23 is a view of a dose counter of the inhaler of FIG. 21;

FIG. 24 is an exploded view of the dose counter shown in FIG. 23;

FIG. 25 is an exploded view of parts of the inhaler of FIG. 21; and

FIG. 26 is a view of a yoke of the inhaler of FIG. 21.

# DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a main body 10 of a manually operated metered dose inhaler 12 in accordance with an embodiment related to the present invention and having a mouthpiece cap 14 securable over a mouthpiece 16 of the main body.

The main body has a canister chamber 18 into which a canister 20 (FIG. 7A) is slideable. The canister 20 has a generally cylindrical main side wall 24, joined by a tapered section 26 to a head portion 28 having a substantially flat lower face 30 which has an outer annular drive surface 32 arranged to engage upon and drive an actuation pin 34 of a dose counter 36 as will be described. Extending centrally and axially from the lower face 30 is a valve stem 38 which is arranged to sealingly engage in a valve stem block 40 of the main body 10 of the inhaler 12. The valve stem block 40 has a passageway 42 leading to a nozzle 44 for directing the contents of the canister 20, namely active drug and propellant, towards an air outlet 46 of the inhaler main body 12. It will be appreciated that due to gaps 48 between the canister 20 and an inner wall 50 of the main body 10 of the inhaler 12 an open top 52 of the main body 10 forms an air inlet into the inhaler 12 communicating via air passageway 54 with the air outlet 46, such that canister contents exiting nozzle 44 mix with air being sucked by the user through the air passageway 54 in order to pass together through the air outlet and into the mouth of the user (not shown).

The dose counter 36 will now be described. The dose counter 36 includes an actuation pin 34 biased upwardly from underneath by a return spring 56 once installed in the main body 10. As best shown in FIGS. 4A, 6H and 8A, the pin 34 has side surfaces 58, 60 arranged to slide between corresponding guide surfaces 62, 64 located in a dose counter chamber 66 of the main body 10, as well as an end stop surface 68 arranged to engage a corresponding end stop 70 formed in the dose counter chamber 66 to limit upward movement of the pin 34. The pin 34 has a top part 72 which is circularly cylindrical and extends through an aperture 74 formed through a separator wall 76 which separates the canister chamber 18 from the dose counter chamber 66. The top part 72 of the pin 34 has a flat top surface 78 which is arranged to engage the outer annular drive surface 32 of the canister 20.

The actuation pin 34 is integrally formed with a drive or actuator pawl 80. The actuator pawl 80 has a generally inverted U-shape configuration, having two mutually spaced and parallel arms 82, 84 extending from a base portion of the actuation pin 34, each holding at respective distal ends 88 thereof opposite ends of a pawl tooth member 90 which extends in a direction substantially perpendicular to the arms 82, 84, so as to provide what may be considered a "saddle" drive for pulling on each of the 11 drive teeth 92 of a ratchet wheel 94 of an incremental drive system 96 or ratchet mechanism 96 of the dose counter 36. As shown for example in FIG. 10B, the pawl tooth member 90 has a sharp lower

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longitudinal side edge 98 arranged to engage the drive teeth 92, the edge-to-surface contact provided by this engagement providing very accurate positioning of the actuator pawl 80 and resultant rotational positioning of the ratchet wheel 94.

The dose counter 36 also has a chassis preassembly 100 which, as shown in FIGS. 4A and 6A, includes a chassis 102 having a first shaft 104 receiving the ratchet wheel 94 which is secured to a tape reel shaft 106, and a second shaft (or split pin) 108 which is parallel to and spaced from the first shaft 104 and which slidably and rotationally receives a tape stock bobbin 110.

As shown in FIG. 6B, when the inhaler has not been used at all, the majority of a tape 112 is wound on the tape stock bobbin 110 and the tape 112 has a series of regularly spaced numbers 114 displayed therealong to indicate a number of remaining doses in the canister 20. As the inhaler is repeatedly used, the ratchet wheel 94 is rotated by the actuator pawl 80 due to operation of the actuation pin 34 by the canister 20 and the tape 112 is incrementally and gradually wound on to the tape reel shaft 106 from the second shaft 108. The tape 112 passes around a tape guide 116 of the chassis 102 enabling the numbers 114 to be displayed via a window 118 in a dose counter chamber cover 120 having a dose marker 132 formed or otherwise located thereon.

As shown in FIGS. 6A and 6D, the second shaft 108 is forked with two forks 124, 126. The forks 124, 126 are biased away from one another. The forks have located thereon at diametrically opposed positions on the second shaft 108 friction or control elements 128, 130, one on each fork. Each control element extends longitudinally along its respective fork 124, 126 and has a longitudinally extending friction surface 132, 134 which extends substantially parallel to a longitudinal axis of the second shaft and is adapted to engage inside a substantially cylindrical bore 136 inside the tape stock bobbin 110. This control arrangement provided between the bore 136 and the control elements 128, 130 provides good rotational control for the tape stock bobbin 110 such that it does not unwind undesirably such as when the inhaler is dropped. The tape force required to unwind the tape stock bobbin 110 and overcome this friction force is approximately 0.1 N.

As can be seen in FIG. 6D, as well as FIGS. 6G and 10A to 10F, the chassis 102 is provided with an anti-back drive tooth 138 or count pawl 138 which is resiliently and substantially fixedly mounted thereto. As will be described below and as can be seen in FIGS. 10A to 10F, when the actuation pin 34 is depressed fully so as to fire the metered valve (not shown) inside the canister 20, the actuator pawl 80 pulls down on one of the teeth 92 of the ratchet wheel 94 and rotates the wheel 94 anticlockwise as shown in FIG. 6D so as to jump one tooth 92 past the count pawl 138, thereby winding the tape 112 a distance incrementally relative to the dose marker 122 on the dose counter chamber 120 so as to indicate that one dose has been used.

With reference to FIG. 10B, the teeth of the ratchet wheel 94 have tips 143 which are radiused with a 0.1 mm radius between the flat surfaces 140, 142. The ratchet wheel 94 has a central axis 145 which is 0.11 mm above datum plane 220 (FIG. 9). A top/nose surface 147 of the anti-back drive tooth 138 is located 0.36 mm above the datum plane 220. The distance vertically (i.e. transverse to datum plane 220—FIG. 9) between the top nose surface 147 of the anti-back drive tooth is 0.25 mm from the central axis 145 of the wheel 94. Bump surface 144 has a lateral extent of 0.20 mm, with a vertical length of a flat 145' thereof being 1 mm, the width of the bump surface being 1.22 mm (in the direction of the axis 145), the top 149 of the bump surface 144 being 3.02

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mm vertically below the axis 145, and the flat 145' being spaced a distance sideways (i.e. parallel to the datum plane 220) 2.48 mm from the axis 145. The top surface 78 of the pin 34 (FIG. 6H) is 11.20 mm above the datum plane 220 (FIG. 9) when the actuator pawl 80 and pin 34 are in the start configuration. The length of the valve stem 22 is 11.39 mm and the drive surface 32 of the canister 20 is 11.39 mm above the datum plane 220 when the canister is at rest waiting to be actuated, such that there is a clearance of 0.19 mm between the canister 20 and the pin 34 in this configuration.

FIGS. 10A and 10B show the actuator pawl 80 and ratchet wheel 94 and count pawl 138 in a start position in which the flat top 78 of the pin 34 has not yet been engaged by the outer annular drive surface 32 of the canister 20 or at least has not been pushed down during a canister depression.

In this "start" position, the count pawl 138 engages on a non-return back surface 140 of one of the teeth 92 of the ratchet wheel 94. The lower side edge 98 of the actuator pawl is a distance "D" (FIG. 9) 1.33 mm above datum plane 220 which passes through bottom surface or shoulder 41 of valve stem block 40, the datum plane 220 being perpendicular to a main axis "X" of the main body 10 of the inhaler 12 which is coaxial with the centre of the valve stem block bore 43 and parallel to a direction of sliding of the canister 20 in the main body 10 of the inhaler 12 when the canister is fired.

As shown in FIG. 10B, an advantageous feature of the construction is that the pawl tooth/actuator 90 acts as a supplementary anti-back drive member when the inhaler 12 is not being used for inhalation. In particular, if the inhaler 12 is accidentally dropped, resulting in a jolt to the dose counter 36 then, if the wheel 94 would try to rotate clockwise (backwards) as shown in FIG. 10B, the back surface 140 of a tooth will engage and be blocked by the tooth member 90 of the pawl 80. Therefore, even if the anti-back drive tooth 138 is temporarily bent or overcome by such a jolt, undesirable backwards rotation of the wheel 94 is prevented and, upon the next canister firing sequence, the pawl 90 will force the wheel 94 to catch up to its correct position so that the dose counter 36 continues to provide correct dosage indication.

FIG. 10C shows a configuration in which the actuator pawl 80 has been depressed with the pin 34 by the canister 20 to a position in which the side edge 98 of the pawl tooth member 90 is just engaged with one of the teeth 92 and will therefore upon any further depression of the pin 34 begin to rotate the wheel 94. This is referred to as a "Reset" position or configuration. In this configuration, the lower side edge 98 of the actuator 80 is 0.64 mm above the datum plane 220.

FIG. 10D shows a configuration in which the actuator pawl 80 has been moved to a position lower than that shown in FIG. 10C and in which the metered dose valve (not shown) inside the canister has at this very position fired in order to eject active drug and propellant through the nozzle 44. It will be noted that in this configuration the count pawl 138 is very slightly spaced from the back surface 140 of the same tooth 92 that it was engaging in the configuration of FIG. 10D. The configuration shown in FIG. 10D is known as a "Fire" configuration. In this configuration the lower side edge 98 of the actuator 80 is 0.47 mm below the datum plane 220.

FIG. 10E shows a further step in the sequence, called a "Count" position in which the actuator pawl 80 has rotated the ratchet wheel 94 by the distance circumferentially angularly between two of the teeth 92, such that the count pawl 138 has just finished riding along a forward surface 142 of one of the teeth 92 and has resiliently jumped over the tooth



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into engagement with the back surface **140** of the next tooth. Accordingly, in this "Count" configuration, a sufficiently long stroke movement of the pin **34** has occurred that the tape **112** of the dose counter **36** will just have counted down one dose. In this configuration, the lower side edge **98** of the actuator is 0.95 mm below the datum plane **220**. Accordingly, in this position, the actuator **80** generally, including edge **98**, is 0.48 mm lower than in the fire configuration. It has been found that, although the count configuration happens further on than the fire configuration, counting is highly reliable, with less than 50 failed counts per million. This is at least partially due to momentum effects and to the canister releasing some back pressure on the user in some embodiments as its internal metering valve fires.

In the configuration of FIG. **10F**, the pawl **80** has been further depressed with the pin **34** by the canister **20** to a position in which it is just disengaging from one of the teeth **92** and the actuator pawl **80** is assisted in this disengagement by engagement of one of the arms **84** with a bump surface **144** on the chassis **102** (see FIG. **6G**) and it will be seen at this point of disengagement, which is called an "End" configuration, the count pawl **138** is positioned exactly halfway or substantially halfway between two of the drive teeth **92**. This advantageously means therefore that there is a minimum chance of any double counting or non-counting, which would be undesirable. In the end configuration, the side edge **98** of the actuator is 1.65 mm below the datum plane **220**. It will be appreciated that any further depression of the actuator pawl **80** and pin **34** past the "End" configuration shown in FIG. **10F** will have no effect on the position of the tape **112** displayed by the dose counter **36** since the actuator pawl **80** is disengaged from the ratchet wheel **94** when it is below the position shown in FIG. **10F**.

As shown in FIGS. **7C** and **7D**, the inner wall **50** of the main body **10** is provided with a two-step support rail **144** which extends longitudinally along inside the main body and is located directly adjacent the aperture **74**. As shown in FIG. **7B** a diametrically opposed two-step support rail **146** is also provided and this diametrically opposed in the sense that a vertical plane (not shown) can pass substantially directly through the first rail **144**, the aperture **74**, a central aperture **148** of the valve stem block **40** (in which canister stem **25** is located) and the second two-step support rail **146**. As shown in FIG. **7A** and schematically in FIG. **7B**, the rails **144**, **146** provide a maximum clearance between the canister **20** and the rails **144**, **146** in a radial direction of almost exactly 0.3 mm, about 0.25 to 0.35 mm being a typical range. This clearance in this plane means that the canister **20** can only rock backwards and forwards in this plane towards away from the actuation pin **34**. A relatively small distance and this therefore prevents the canister wobbling and changing the height of the actuation pin **34** as to undesirably alter the accuracy of the dose counter **36**. This is therefore highly advantageous.

The inner wall **50** of the main body **10** is provided with two further two-step rails **150** as well as two pairs **152**, **154** of rails extending different constant radial amounts inwardly from the inner wall **50**, so as to generally achieve a maximum clearance of almost exactly 0.3 mm around the canister **20** for all of the rails **144**, **146**, **150**, **152**, **154** spaced around the periphery of the inner wall **50**, in order to prevent undue rocking while still allowing canister motion freely inside the inhaler **12**. It will be clear from FIG. **7C** for example that the two-step rails have a first portion near an outlet end **156** of the canister chamber **18**, the first portion having a substantially constant radial or inwardly-extending width, a first step **160** leading to a second portion **162** of the rail, the

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second portion **102** having a lesser radial or inwardly extending extent than the first portion **156**, and finally a second step **164** at which the rail merges into the main inner wall **50** main surface.

A method of assembling the inhaler **12** will now be described.

With reference to FIG. **8A**, the main body **10** of the inhaler **12** is formed by two or more plastics mouldings which have been joined together to the configuration shown.

As shown in FIG. **8B**, the actuator pawl **80** and pin **34** are translated forward into position into a pin receiving area **166** in the dose counter chamber **66** and the pin **34** and actuator **80** may then be raised until the pin **34** emerges through the aperture **74**.

Next, the return spring **56** may be inserted below the pin **34** and a generally cylindrical annular lower end **168** of the spring **56** may be moved by a tweezer or tweezer-like assembly tool (not shown) into engagement with a shelf **170** of a spring retainer **172** in the dose counter chamber **66**. The spring retainer **172** is U-shaped and the shelf **170** is U-shaped and has a recess **174** formed below it. As shown in FIGS. **4B**, **4C** and **12** shelf **170** includes three chamfer surfaces **176**, **178**, **180** arranged to assist in moving the lower end of the spring **168** into position onto the shelf using the assembly tool (not shown). Once the lower end of the spring **168** is in place, the assembly tool (not shown) can easily be removed at least partly via the recess **174** below the lower end **168** of the spring **56**.

The tape **112** is attached at one end (not shown) to the tape stock bobbin **110** and is wound onto the bobbin by a motor **200** (FIG. **13**) having a hexagonal output shaft **202** which engages in a hexagonal socket **204** (FIG. **6B**) of the bobbin. During winding, the tape is monitored by a sensor **206**, which may be in the form of a camera or laser scanner, which feeds data to a computer controller **205** for the motor **200**. The controller **205** recognises three positioning markers **210** in the form of lines across the tape **112** and stops the motor **202** when the tape **112** is nearly fully wound onto the bobbin **110**, such that the distal end **212** of the tape **112** can be secured, e.g. by adhesive, to the tape reel shaft **106**. The controller **205** also recognises a pixelated tape size marker **214** observed by the sensor **206** and logs in a stocking system data store **217** details of the tape **112** such as the number of numbers **114** on the tape, such as one hundred and twenty or two hundred numbers **114**. Next, the tape reel shaft is wound until an appropriate position of the lines **210** at which a priming dot **216** will, once the bobbin **110** and reel shaft **106** are slid onto the second shaft **108** and second shaft **104**, be in a position to be located in the window **118** when the inhaler **12** is fully assembled. In the embodiments, the bobbin **110** and reel shaft **106** may be slid onto the shafts **108**, **104** before the tape **112** is secured to the reel shaft **106** and the reel shaft may then be wound to position the priming dot **216**.

Next, the assembled dose counter components of the chassis preassembly **100** shown in FIG. **6B** may as shown in FIG. **8C** be inserted into the dose counter chamber **66**, with pins **182**, **184**, **186** formed on the main body **10** in the dose counter chamber **66** passing through apertures or slots **188**, **190**, **192** formed on the chassis **102**, such that the pins **182**, **184**, **186** extend through (or at least into) the apertures or slots **188**, **190**, **192**. With the chassis **102** being relatively firmly pushed towards the main body **10**, the pins **182**, **184**, **186** are then heat staked and the chassis **102** is therefore after this held very firmly in position in the main body and is unable to move, thereby assisting in providing great accuracy for the dose counter **36**. Next, as shown in FIG. **8D**, the

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dose counter chamber cover **120** may be fitted over the dose counter chamber **66** and may be secured in place such as by welding, with the priming dot **216** being displayed through the window.

The user can, when readying the inhaler **12** for first use, prime the inhaler by depressing the canister **20** three times which will bring the first number **114** on the tape into display through the window **118** in place of the priming dot **216**, the number **114** shown in FIG. **8D** being “200”, thereby indicating that 200 doses are remaining to be dispensed from the canister **20** and inhaler **12**.

As shown in FIG. **8D**, and in FIG. **5**, an open drain hole **194** is provided at the bottom of the dose counter chamber **66** by a substantially semi-circular cut-out or recess formation **196** in a lower surface **198** of the main body **10** of the inhaler. Accordingly, if the user (not shown) should decide to wash the main body **10** of the inhaler, for example after encountering an unhygienic situation or simply as a matter of choice, the drain hole **194** allows initial draining of water from inside the dose counter chamber **66** and also thereafter evaporation of water or any aqueous matter in the dose counter chamber **66** so that the window **118** does not mist up undesirably.

FIG. **14** shows a computer system **230** for designing the dose counter **36** and in particular for calculating distributions representative of average positions and standard deviations in a production series of inhalers of the start, reset, fire, count and end positions of the actuator lower side edge **98** relative to the datum plane **220** (FIG. **9**) and therefore of the actuator pawl **80** generally relative to the ratchet wheel **94**, chassis **102** and, when the inhaler **12** is fully assembled, the main body **10** of the inhaler **12**. The computer system **230** includes a data store **232**, a CPU **234**, an input device **236** (such as a keyboard or communication port) and an output device **238** (such as a communications port, display screen and/or printer). A user may enter data via the input device **236** which may be used by the CPU **234** in a mathematical calculation to predict count failure rates when the various dose counters are to be built in a series with dose counter positions set with given averages and standard deviations and taking into account any momentum/inertia effects and metering valve user-back-pressure reduction effect which will occur upon canister firing of a given type of canister. The computer system **230** is thus mathematically used to design the distributions. For the inhaler **12** described herein with the dose counter **36** and canister **20**, the distributions are designed as shown in FIG. **11**. The x axis shows distance of the lower side surface **98** of the actuator **80** above the datum plane **220** and the y axis is representative of the distribution. Thus, curve **240** shows that the start configuration has an average 1.33 mm above the datum plane **200** (standard deviation is 0.1 mm), curve **242** shows that the reset configuration has an average of 0.64 mm above the datum plane **220** (standard deviation is 0.082 mm), curve **244** shows the fire configuration has an average 0.47 mm below the datum plane **220** (standard deviation is 0.141 mm), curve **246** shows the count configuration has an average 0.95 mm below the datum plane **220** (standard deviation is 0.080 mm), and curve **248** shows the end configuration has an average of 1.65 mm below the datum plane **220** (standard deviation is 0.144 mm).

FIGS. **15** to **20** show a version of the inhaler modified in accordance with the present invention. In these drawings, the same reference numerals have been used to those in the earlier drawings to denote the equivalent components. The inhaler **12** is the same as that in FIGS. **1** to **14** apart from the following modifications.

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First, it can be seen that there is a modification in that the drive teeth **92** of the ratchet wheel **94** have a different profile to that in FIGS. **1** to **14**. There are also only nine ratchet teeth **94** in this embodiment instead of eleven.

Additionally, as shown in FIGS. **18C** and **19C**, the control elements **128**, **130** on the forks **124**, **126** of the second shaft **108** have a tapered profile which is different to the profile of the control elements **128**, **130** shown in FIG. **6F**. Either profile can be used in the embodiment of FIGS. **15** to **20** however.

Furthermore, as shown in FIG. **15**, the tape stock bobbin **110** has an inwardly facing generally cylindrical engagement surface **300** with a wavelike form extending partially therealong. The engagement surface **300** has a cross-section **301** perpendicular to the longitudinal length of the stock bobbin **110** which is constant therealong. This cross-section **301** can be seen in FIG. **16** and consists of a series of ten regularly spaced concavities **302** and ten convex wall portions **304**. The convex wall portions **304** are equi-spaced between the concavities **302**. Each concavity **302** has a radius of 0.2 mm. Each convex wall portion **304** also has a radius of 0.2 mm. Finally, the cross section **301** also includes flat wall portions **306** between all of the radiused wall portions of the concavities **302** and convex wall portions **304**. The geometry of the cross-section **301** is therefore defined by the radii of the concavities **302** and convex wall portions **304**, the flat wall portions **306** and the fact that there are ten concavities **302** and convex wall portions **304**.

The minor diameter of the engagement surface **300**, i.e. between the tips of opposite convex wall portions **304**, is 2.46 mm. The major diameter of the engagement surface **300**, i.e. between the outermost portions of the concavities **302**, is 2.70 mm. The undeformed tip to tip maximum diameter of the forks **124**, **126** of the split pin (the second shaft) **108**, i.e. in the region of the maximum radio extent of the control elements **128**, **130**, is 3.1 millimetres and it will therefore be appreciated that the forks **124**, **126** are resiliently compressed once the stock bobbin **110** has been assembled onto the split pin **108** in all rotational configurations of the stock bobbin **110** relative to the split pin **108**. The minimum gap between the forks **124**, **126** in the plane of the cross sections of FIGS. **18C** and **19C** is 1 mm when the split pin **108** is in the undeformed, pre-inserted state. When the split pin **108** is at maximum compression, as shown in FIGS. **18A** to **18C** when the control elements **128**, **130** are shown to be engaged on top of the convex wall portions **304**, the gap **308** between the tips **310**, **312** of the forks **124**, **126** is 0.36 mm. On the other hand, when the split pin **108** is at minimum compression (once inserted into the stock bobbin) as shown in FIGS. **19A** to **19C**, when the control elements **128**, **130** rest in the concavities **302**, the gap between the tips **310**, **312** of the forks **124**, **126** is 0.6 mm. The control elements **128**, **130** are outwardly radiused with a radius also of 0.2 mm such that they can just rest on the concavities **302** with full surface contact (at least at an axial location on the split pin where the tapered control elements are at their maximum radial extent), without rattling in, locking onto or failing to fit in the concavities **302**. The radii of the control elements **128**, **130** is therefore preferably substantially the same as the radii of the concavities **302**.

It will be appreciated that whereas FIGS. **18B** and **19B** are end views along the coaxial axis of the stock bobbin **110** and split pin **108**, FIGS. **18A** and **19A** are cross-sections. FIG. **19A** is a section on the plane A-A' in FIG. **19C** and FIG. **18A** is a section at the same plane, but of course with the stock bobbin **110** rotated relative to the split pin **108**.

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As the inhaler 12 is used and the ratchet wheel 94 rotates in order to count used doses, the stock bobbin rotates incrementally through rotational positions in which rotation is resisted, i.e. due to increasing compression of the split pin 108 at such rotational positions, and rotational positions in which rotation is promoted, i.e. due to decreasing compression of the split pin 108 at such rotational positions and this may involve a click forward of the stock bobbin 110 to the next position equivalent to that in FIGS. 19A to 19C in which the control elements 128, 130 of the split pin art located in the concavities 302. This functionality firstly allows the stock bobbin to unwind during use as required, but also prevents the tape 112 from loosening during transit if the inhaler 12 is dropped, such as onto a hard surface. This is highly advantageous, since the tape 11 is prevented from moving to a position in which it will give an incorrect reading regarding the number of doses in the canister.

During compression and expansion of the forks in the radial direction between the two configurations shown in FIGS. 18C and 19C, the forks 124, 126 rotate about a point 316 on the split pin where the forks 124, 126 come together. This rotational action means that there is a camming action between the forks 124, 126 and the engagement surface 300 without significant friction but, nevertheless, the resilient forces provided by the regulator formed by the engagement surface 300 and forks 124, 126 are able to regulate unwinding of the tape such that it does not easily occur during transit or if the inhaler 12 is dropped. It has been found during testing that a force of 0.3 to 0.4 N needs to be applied to the tape 112 to overcome the regulator at the stock bobbin 110. 0.32 N is achieved with the control elements 128 having the profile shown in FIG. 19C and 0.38 N is achieved with the profile of the control elements 128 altered to be as shown as described with reference to FIG. 6F. These forces are substantially higher than the 0.1 N force mentioned above and undesirable movement of the tape is substantially avoided even if the inhaler is dropped onto a hard surface. The modified arrangement of FIGS. 15 to 20 does not provide this force "constantly" such that there is overall not an undesirably high friction of the tape 112 as it passes over the other components of the dose counter because, due to the incremental nature of the resilient forces at the regulator, the tape 112 can incrementally relax as it slides over the stationary chassis components.

Instead of having ten concavities 302 and convex wall portions 304, other numbers may be used, such as 8 or 12. However, it is preferred to have an even number, especially since two control elements 128, 130 are provided, so that all of the control elements 128, 130 will expand and contract simultaneously. However, other arrangements are envisaged with 3 or more forks and the number of concavities/convex wall portions may be maintained as an integer divisible by the number of forks to maintain a system with simultaneous expansion/contraction. For example, the use of 9, 12 or 15 concavities/convex wall portions with 3 forks is envisaged.

Instead of having the engagement surface 300 on the inside of the stock bobbin 110, it could be placed on the outside of the stock bobbin 110 so as to be engaged by flexible external legs/pawls or similar.

It will be noted that the regulator provided by the engagement surface 300 and forks 124, 126 does not only allow rotation of the stock bobbin in one direction as is the case with the ratchet wheel 94. Rotation in both directions is possible, i.e. forwards and backwards. This means that during assembly, the stock bobbin 110 can be wound backwards during or after fitting the bobbin 100, shaft 106 and tape 112 onto the carriage 102, if desired.

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The stock bobbin 110 and the carriage 102 including the split pin 108 are both moulded of polypropylene material.

It will be seen from FIG. 16 that the cross-sectional shape 301 is not symmetrical within the hexagonal socket 204. This has enabled the hexagonal socket 204 to be maintained at a useful size while still allowing the desired size and geometry of the cross section 301 to fit without interfering with the hexagonal shape of the hexagonal socket 204 and also permits moulding to work during manufacture.

As shown in FIG. 17, the stock bobbin 110 has a series of four circumferential ribs 330 inside it and a spaced therealong. These hold the stock bobbin 110 on the correct side of the mould tool during moulding.

FIGS. 21 and 22 show a preferred embodiment in accordance with the invention of an inhaler 510 for dispensing a dry-powdered medicament in metered doses for patient inhalation. The inhaler 510 is as disclosed in FIGS. 1 to 16 or EP-A-1330280, the contents of which are hereby fully incorporated herein by reference, but with the stock bobbin 110 and second shaft 108 of the dose counter 516 modified so as to be as in FIGS. 15 to 20 hereof. Thus, the dry powder inhaler 510 generally includes a housing 518, and an assembly 512 received in the housing (see FIG. 21). The housing 518 includes a case 520 having an open end 522 and a mouthpiece 524 (FIG. 25) for patient inhalation, a cap 526 secured to and closing the open end 522 of the case 520, and a cover 528 pivotally mounted to the case 520 for covering the mouthpiece 524. As shown in FIG. 22, the inhaler 510 also includes an actuation spring 569, first yoke 566 with opening 572, bellows 540 with crown 574, a reservoir 514, second yoke 568 with hopper 542 and dose counter 516 mounted thereto, and case 520 has transparent window 5130 thereon for viewing dose counter tape indicia 5128. The dose metering system also includes two cams 570 mounted on the mouthpiece cover 528 and movable with the cover 528 between open and closed positions. The cams 570 each include an opening 580 for allowing outwardly extending hinges 582 of the case 520 to pass therethrough and be received in first recesses 584 of the cover 528. The cams 570 also include bosses 586 extending outwardly and received in second recesses 588 of the cover 528, such that the cover 528 pivots about the hinges 582 and the cams 570 move with the cover 528 about the hinges 582. As described in EP-A-1330280, cams 570 act upon cam followers 578 to move second yoke 568 up and down and thereby operate dose counter by engagement of pawl 5138 on the second yoke 568 with teeth 5136. Remaining components of the inhaler are provided as, and operate as described, in EP-A-1330280.

The dose counting system 516 therefore includes a ribbon or tape 5128 (FIGS. 23 & 24), having successive numbers or other suitable indicia printed thereon, in alignment with a transparent window 5130 provided in the housing 18 (see FIG. 22). The dose counting system 516 includes the rotatable stock bobbin 110 (as described above), an indexing spool 5134 rotatable in a single direction, and the ribbon 5128 rolled and received on the bobbin 110 and having a first end 5127 secured to the spool 5134, wherein the ribbon 5128 unrolls from the bobbin 110 so that the indicia are successively displayed as the spool 5134 is rotated or advanced. In FIGS. 23 and 24 the wavelike engagement surface 300 of the bobbin 110 is not shown for the purposes of clarity.

The spool 134 is arranged to rotate upon movement of the yokes 566, 568 to effect delivery of a dose of medicament from reservoir 514, such that the number on the ribbon 5128 is advanced to indicate that another dose has been dispensed by the inhaler 510. The ribbon 5128 can be arranged such that the numbers, or other suitable indicia, increase or



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decrease upon rotation of the spool **5134**. For example, the ribbon **5128** can be arranged such that the numbers, or other suitable indicia, decrease upon rotation of the spool **5134** to indicate the number of doses remaining in the inhaler **510**. Alternatively, the ribbon **5128** can be arranged such that the numbers, or other suitable indicia, increase upon rotation of the spool **5134** to indicate the number of doses dispensed by the inhaler **10**.

The indexing spool **5134** includes radially extending teeth **5136**, which are engaged by pawl **5138** extending from a cam follower **578** of the second yoke **568** upon movement of the yoke to rotate, or advance, the indexing spool **5134**. More particularly, the pawl **5138** is shaped and arranged such that it engages the teeth **5136** and advances the indexing spool **5134** only upon the mouthpiece cover **528** being closed and the yokes **566**, **568** moved back towards the cap **526** of the housing **518**.

The dose counting system **516** also includes a chassis **5140** that secures the dose counting system to the hopper **542** and includes shafts **108**, **5144** for receiving the bobbin **110** and the indexing spool **5134**. As described above with reference to FIGS. **1** to **20**, the bobbin shaft **108** is forked and includes radially nubs **5146** for creating a resilient resistance to rotation of the bobbin **110** on the shaft **108** by engaging with the wavelike engagement surface **300** inside the bobbin **110**. A clutch spring **5148** is received on the end of the indexing spool **5134** and locked to the chassis **5140** to allow rotation of the spool **5134** in only a single direction.

Various modifications may be made to the embodiment shown without departing from the scope of the invention as defined by the accompanying claims as interpreted under patent law.

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What is claimed is:

**1.** An inhaler for inhaling medicament, the inhaler having: A body for retaining a medicament canister; and a dose counter, the dose counter having a moveable actuator and a chassis mounted on the body; wherein one of the body and the chassis includes a plurality of apertures for receiving one or more pins on the other of the body and the chassis, wherein either the pins or the apertures on the chassis are positioned on different sides of the chassis for stabilizing the chassis on the body, and wherein the chassis comprises at least one of a pin or aperture heat staked to a respective aperture or pin of the body to mount the chassis to the body.

**2.** The inhaler as claimed in claim **1**, wherein the dose counter is positioned in a dose counter chamber that is formed in the body at a location beneath the medicament canister.

**3.** The inhaler as claimed in claim **2** further comprising a cover that is fixed to the body to conceal the dose counter chamber.

**4.** The inhaler as claimed in claim **1**, wherein the medicament canister is movable relative to the dose counter.

**5.** The inhaler as claimed in claim **1**, wherein the body has a canister housing and the medicament canister is moveable relative to the canister housing, wherein at least a portion of the movable actuator of the dose counter is located in the canister housing for operation by movement of the medicament canister.

**6.** The inhaler as claimed in claim **1**, wherein either the pins or the apertures on the chassis are positioned on three different sides of the chassis for stabilizing the chassis on the body.

\* \* \* \* \*

## **EXHIBIT 6**

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# Guidance for Industry

## Integration of Dose-Counting Mechanisms into MDI Drug Products

**U.S. Department of Health and Human Services  
Food and Drug Administration  
Center for Drug Evaluation and Research (CDER)  
Clinical Medical  
March 2003**

# Guidance for Industry

## Integration of Dose-Counting Mechanisms into MDI Drug Products

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**U.S. Department of Health and Human Services  
Food and Drug Administration  
Center for Drug Evaluation and Research (CDER)  
Clinical Medical**

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*Contains Nonbinding Recommendations*

## **Guidance for Industry <sup>1</sup> Integration of Dose-Counting Mechanisms into MDI Drug Products**

This guidance represents the Food and Drug Administration's (FDA's) current thinking on this topic. It does not create or confer any rights for or on any person and does not operate to bind FDA or the public. An alternative approach may be used if such approach satisfies the requirements of the applicable statutes and regulations. If you want to discuss an alternative approach, contact the FDA staff responsible for implementing this guidance. If you cannot identify the appropriate FDA staff, call the appropriate number listed on the title page of this guidance.

### **I. INTRODUCTION**

This guidance is intended to assist manufacturers who are developing or plan to develop drug products for oral inhalation using metered-dose inhalers (MDIs). The guidance reflects the Agency's current recommendations regarding the integration of dose-counting mechanisms into MDI drug products for oral inhalation. Although the contents of the guidance should be *considered* by any manufacturer of *any* MDI drug product (including nasal MDI products), this guidance is not specifically intended for manufacturers of already marketed MDI drug products for oral inhalation nor for manufacturers developing MDIs for other routes of administration (e.g., nasal MDIs). It is also not intended for manufacturers developing multidose dry powder inhalers (MDPIs), which already incorporate dose counters as an integral part of the delivery system. Manufacturers developing new MDPIs are encouraged to continue including dose counters in their products and may find the contents of this guidance useful in their planning.

For the purposes of this guidance, the term *dose counter* includes both mechanisms that use a numeric count to indicated doses remaining, as well as dose-indicating mechanisms that do not enumerate the number of actuations, but rather indicate via color coding or other means when a device is nearing the end of its useful life. Also, the use of the term *integrated* in this document is intended to define dose counters that are an integral part of the MDI canister and/or actuator, and not simply an add-on that can be removed and used multiple times with various products.

FDA's guidance documents, including this guidance, do not establish legally enforceable responsibilities. Instead, guidances describe the Agency's current thinking on a topic and should be viewed only as recommendations, unless specific regulatory or statutory requirements are

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<sup>1</sup> This guidance has been prepared by the Division of Pulmonary and Allergy Drug Products in the Center for Drug Evaluation and Research (CDER) at the Food and Drug Administration (FDA).



***Contains Nonbinding Recommendations***

cited. The use of the word *should* in Agency guidances means that something is suggested or recommended, but not required.

## **II. BACKGROUND**

Metered-dose inhalers have been available for nearly 50 years and have come to be regarded as the preferred method of delivery for many important drugs intended to treat obstructive airway diseases, such as asthma, emphysema, and chronic bronchitis.<sup>2</sup> MDIs represent a reliable, convenient dosing device for delivery of medications to the lungs. However, they have one major disadvantage over other dosage forms. Currently available MDIs offer no practical way for patients to track the remaining numbers of doses or amount of medication. A complicating, but necessary design feature of MDIs is that they contain more formulation than strictly required to expel the labeled number of actuations. This additional amount of formulation (propellant, drug substance, and any excipients) is necessary to ensure the dosing consistency of each spray through the labeled number. For instance, an MDI labeled to deliver 120 metered-actuations may expel 20 to 30 additional actuations (depending on the specific fill target for that product). However, the amount of drug per spray in those additional 20 to 30 actuations may in many cases be inconsistent and with continued use beyond the label claim will become negligible. Since the inactive components in the drug formulation may exceed 95 to 99 percent, an MDI used beyond the recommended dose may appear to be delivering a therapeutic spray when it isn't. Other than carefully and consistently tracking each actuation in writing and subtracting this total from the labeled number of actuations, there is no method by which a patient can determine how many effective doses are left in an MDI. Various means of *testing* the inhalers (e.g., shaking the canister) are unreliable and some in addition may damage the MDI (e.g., the *float-test*, placing the canister in water).

Currently, patients must guess how many doses are left in their MDIs and have two practical options: (1) throw away an MDI that may still contain acceptable metered-doses or (2) use a product when it may be beyond the recommended number of doses and risk not receiving the correct drug dose. The former is wasteful, and the latter is potentially dangerous. The addition of an accurate dose counter to an individual MDI unit would allow the patient to reliably track the numbers of actuations used from that individual inhaler (i.e., to identify when the label claim number of actuations has been reached). This would prevent the patient from discarding an inhaler unnecessarily or using the product beyond the recommendations provided in the labeling for that product.

The recommendations in this guidance address primarily MDI products designed to deliver drugs to the lungs for any indication. This is because the consequences of not receiving an acceptable metered dose are more clinically important for oral inhalation drug products than for the current medications available in nasal MDIs. Medications delivered to the lungs often play a vital role in the treatment of airway diseases and are potentially life-saving. Nasally delivered drugs are more typically intended to treat bothersome, but non-life-threatening, conditions. However, if a

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<sup>2</sup> *Guidelines for the Diagnosis and Management of Asthma: Expert Panel Report 2*, National Asthma Education and Prevention Program of the National Institutes of Health, NIH publication #97-4051, April 1997.

*Contains Nonbinding Recommendations*

nasal MDI were developed where the issue of dosing beyond the recommended label claimed number of doses were associated with a more serious consequence, this guidance would be applicable.

Finally, this guidance is not intended to preclude other accurate means of informing patients as to the remaining number of metered-doses left in an MDI. If manufacturers develop other ways apart from the use of a dose counter, the FDA is willing to consider those innovations and, if satisfactory, to deem them reasonable alternatives.

### **III. INTEGRATION OF DOSE-COUNTING MECHANISMS INTO MDI PRODUCTS UNDER DEVELOPMENT**

#### **A. General Recommendations**

The Agency recommends that manufacturers with metered-dose inhalers under development for oral inhalation integrate a dose-counting device into the development of their MDI drug product. Dose counters should provide, either through a direct numeric count or color coding, a clear indication of when an MDI is approaching the end of its recommended number of actuations as well as when it has reached or exceeded that number. An indication that an MDI is approaching the end of its recommended number of actuations should occur when a sufficient number of actuations are left to give patients enough time to obtain a new MDI. If a numeric count is chosen, we recommend that the counter be designed so that it counts downward from the recommended number of actuations to zero, rather than counting upwards, enabling patients to know when a device is approaching the end of its life (i.e., the number of actuations is approaching zero).

As previously mentioned, this guidance specifically refers to orally inhaled MDI drug products currently under development or which are being planned for development. Although the integration of dose counters into currently approved MDIs is also encouraged, it is recognized that the economics of doing so may be burdensome, particularly for MDIs using chlorofluorocarbons as propellants (since these products will eventually be universally phased-out under the provisions of the Montreal Protocol on Protection of the Ozone Layer). Manufacturers with MDI drug products in the latter stages of development are encouraged to integrate a dose counter into their product as soon as feasible, although the integration may not be possible prior to submission of a new drug application. In such cases, manufacturers are encouraged to commit to developing an integrated dose counter in the postmarketing period.

#### **B. Reliability Issues**

Dose counters should be engineered to reliably track actuations and should be designed to be as close to 100 percent reliable as possible. However, if some low frequency of error is unavoidable, the device should be designed to specifically avoid undercounting (i.e., the MDI sprays, but the counter does not advance). Undercounting could result in patients assuming they have medication left in their MDI when they do not, a circumstance that is potentially dangerous. The reliability of dose counters should be established during development under in-vitro testing

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(simulating use and potential abuse), as well as in clinical use. The documentation of dose counter functionality, reliability, and accuracy would ideally be derived from assessments in clinical trials including, where possible, phase-3 trials. However, for dose counters added either late in a development program or postapproval, in-use studies should be designed and conducted to obtain this information. Note that in either case, these studies do not need to establish the clinical benefit of incorporating a dose counter, rather, they should address issues related to ergonomics, ruggedness, and accuracy of the counters in clinical settings. The range of patients in whom this information is developed should include reasonable representation of special populations likely to use the drug (e.g., pediatrics, geriatrics). Finally, if the same dose counter design and mechanism is incorporated into multiple different MDIs, it would not ordinarily be necessary to repeat the in-use studies for each additional MDI product in which a counter of the same design is used, once the in-use data have been satisfactorily developed with the device. However, since dosing characteristics vary between MDIs, in-vitro testing would ordinarily be expected in all such cases.

**C. Other Considerations**

A lock-out mechanism to prevent doses beyond the labeled number of actuations would be an optional feature of dose counters. However, a lock-out feature would not be recommended for bronchodilator medications used to treat acute bronchospasm. For these *rescue bronchodilators*, the ability of the MDI to actuate beyond the labeled number of actuations and to provide even a partially therapeutic dose of drug could be life saving.

## **EXHIBIT 7**

## **New Oxford American Dictionary**

# New Oxford American Dictionary

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*Edited by*

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Christine A. Lindberg

FIRST EDITION

Elizabeth J. Jewell

Frank Abate

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### **New Oxford American Dictionary** 1

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## melodic

**me-lod-ic** /mə'lādik/ ► **adj.** of, having, or producing melody: *melodic and rhythmic patterns.* ■ pleasant-sounding; melodious: *his voice was deep and melodic.*

— **DERIVATIVES** **me-lod-i-cal-ly** /-(ə)lē/ **adv.**, **me-lod-i-cism** **n.**

— **ORIGIN** early 19th cent.: from French *mélodique*, via late Latin from Greek *melōidikos*, from *melōidia* 'melody.'

**me-lod-i-ca** /mə'lādika/ ► **n.** a wind instrument with a small keyboard controlling a row of reeds, and a mouthpiece at one end.

— **ORIGIN** 1960s: from **MELODY**, on the pattern of *harmonica*.

**me-lod-ic mi-nor** ► **n.** Music a minor scale with the sixth and seventh degrees raised when ascending and lowered when descending.

**me-lo-di-ous** /mə'lōdēəs/ ► **adj.** of, producing, or having a pleasant tune; tuneful: *the melodious chant of the monks.* ■ pleasant-sounding: *a melodious voice.*

— **DERIVATIVES** **me-lo-di-ous-ly** **adv.**, **me-lo-di-ous-ness** **n.**

— **ORIGIN** late Middle English: from Old French *melodius*, from *melodie* (see **MELODY**).

**mel-o-dist** /melədɪst/ ► **n.** a composer of melodies. ■ a singer.

**mel-o-dize** /mela,diz/ ► **v.** [no obj.] rare make or play music.

**mel-o-dra-ma** /mela,drāmə/ ► **n.** 1 a sensational dramatic piece with exaggerated characters and exciting events intended to appeal to the emotions. ■ the genre of drama of this type. ■ language, behavior, or events that resemble drama of this kind: *what little is known of his early life is cloaked in melodrama.*

2 historical a play interspersed with songs and orchestral music accompanying the action.

— **DERIVATIVES** **mel-o-dram-a-tist** /mela,drāmətɪst/ **n.**, **mel-o-dram-a-tize** /mela,drām,tiz/ **v.**

— **ORIGIN** early 19th cent.: from French *mélodrame*, from Greek *melos* 'music' + French *drame* 'drama.'

**mel-o-dra-mat-ic** /melə,drāmətɪk/ ► **adj.** of or relating to melodrama. ■ characteristic of melodrama, esp. in being exaggerated, sensationalized, or overemotional: *he flung the door open with a melodramatic flourish.*

— **DERIVATIVES** **mel-o-dra-mat-i-cal-ly** /-ik(ə)lē/ **adv.**

**mel-o-dra-mat-ics** /melə,drāmətɪks/ ► **plural n.** melodramatic behavior, action, or writing.

**mel-o-dy** /melədē/ ► **n.** (pl. **melodies**) a sequence of single notes that is musically satisfying: *he picked out an intricate melody on his guitar.* ■ such sequences of notes collectively: *his great gift was for melody.* ■ the principal part in harmonized music: *we have the melody and bass of a song composed by Strozzi.*

— **ORIGIN** Middle English (also in the sense 'sweet music'): from Old French *melodie*, via late Latin from Greek *melōidia*, from *melos* 'song.'

**mel-on** /melən/ ► **n.** 1 the large round fruit of a plant of the gourd family, with sweet pulpy flesh and many seeds.

2 the Old World plant that yields this fruit. ■ *Cucumis melo* subsp. *melo*, family Cucurbitaceae; many varieties.

3 Zoology a mass of waxy material in the head of dolphins and other toothed whales, thought to focus acoustic signals.

4 a large profit, esp. a stock dividend, to be divided among a number of people: *you can just see them sitting around the room cutting up the melon in advance.*

— **ORIGIN** late Middle English: via Old French from late Latin *melo*, *melon*-, contraction of Latin *melo-pepo*, from Greek *mēlopepōn*, from *mēlon* 'apple' + *pepōn* 'gourd.'

**Me-los** /mə'lās/ a Greek island in the Aegean Sea, in the southwest of the Cyclades group. The center of a flourishing civilization during the Bronze Age, it is the site of the discovery in 1820 of a Hellenistic marble statue of Aphrodite, the **VENUS DE MILO**. Greek name **MILOS**.

**Mel-pom-e-ne** /mel'pāmənē/ Greek & Roman Mythology the Muse of tragedy.

— **ORIGIN** Greek, literally 'singer.'

**melt** /melt/ ► **v.** 1 make or become liquefied by heat: [no obj.] *place under the broiler until the cheese has melted* | [with obj.] *the hot metal melted the wax* | *the icebergs were melting away* | (as adj.) *the asparagus with melted butter.* ■ [with obj.] *(melt something down)* melt something, esp. a metal article, so that the material it is made of can be used again: *beautiful objects are being melted down and sold for scrap.* ■ dissolve in liquid: *add a cup of sugar and boil until the sugar melts.*

2 make or become more tender or loving: [no obj.] *she was so beautiful that I melted* | [with obj.] *Richard gave her a smile that melted her heart.*

3 [no obj.] leave or disappear unobtrusively: *the compromise was accepted and the opposition melted away* | *the figure melted into thin air.* ■ **(melt into)** change or merge imperceptibly into (another form or state): *the cheers melted into gasps of admiration.*

► **n.** an act of melting: *the precipitation falls as snow and is released during the spring melt.* ■ metal or other material in a melted condition. ■ an amount melted at any one time. ■ [with modifier] a sandwich, hamburger, or other dish containing or topped with melted cheese: *a tuna melt.*

— **PHRASES** **melt in the (or your) mouth** (of food) be deliciously light or tender and need little or no chewing: *my shortbread melts in the mouth* | [as adj.] *melt-in-your-mouth chicken livers.*

— **PHRASAL VERBS** **melt down** 1 collapse or break down disastrously: *many expected him to melt down at the first sign of trouble.* 2 (of a nuclear reactor) undergo a catastrophic failure as a result of the fuel overheating.

— **DERIVATIVES** **melt-a-ble** **adj.**, **melt-er** **n.**, **melt-ing-ly** **adv.**

— **ORIGIN** Old English *meltan*, *mieltan*, of Germanic origin; related to Old Norse *melta* 'to melt, digest,' from an Indo-European root shared by Greek *meldein* 'to melt,' Latin *mollis* 'soft,' also by **MALT**.

**melt-down** /melt,dəʊn/ ► **n.** 1 a disastrous event, esp. a rapid fall in share prices: *the 1987 stock market meltdown.*

2 an accident in a nuclear reactor in which the fuel overheats and melts the reactor core or shielding.

**WORD TRENDS** A meltdown was originally a catastrophic accident in a nuclear reactor, but this literal meaning has been swamped by the figurative sense of 'a disastrous collapse or breakdown.' This is a fairly recent coinage, first recorded in 1983, with the 'Black Monday' stock market crash of October 1987 labeled a *market meltdown*. The Oxford English Corpus shows a fairly steady use throughout the last decade, but in 2007 there was a massive leap in the number of examples. This reflects the beginning of the recession, with *financial*, *economic*, *global*, and *mortgage* becoming the word's most common collocates: *the global financial meltdown sent oil prices plummeting today.*

**mel-te-mi** /mel'temē/ (also **meltemi wind**) ► **n.** a dry northwesterly wind that blows during the summer in the eastern Mediterranean. Also called **ETESIAN WIND**.

— **ORIGIN** from modern Greek *meltemi*, Turkish *meltem*.

**melting point** ► **n.** the temperature at which a given solid will melt.

**melting pot** ► **n.** a pot in which metals or other materials are melted and mixed. ■ a place where different peoples, styles, theories, etc., are mixed together: *a melting pot of disparate rhythms and cultures.*

**mel-ton** /meltən/ ► **n.** heavy woolen cloth with a close-cut nap, used for overcoats and jackets.

— **ORIGIN** early 19th cent.: named after Melton Mowbray, a town in central England, formerly a center of manufacturing.

**melt-wa-ter** /melt,wōtər, -wātər/ ► **n.** (also **meltwaters**) water formed by the melting of snow and ice, esp. from a glacier.

**Mel-ville** /melvəl, -vil/, Herman (1819–91), US novelist and short-story writer. His experiences on a whaling ship formed the basis of several novels, notably *Moby Dick* (1851). Other notable works: *White-Jacket* (1850), *The Confidence-Man* (1857), and *Billy Budd* (first published in 1924).

**mem.** ► **abbr.** ■ member. ■ memoir. ■ memorandum. ■ memorial.

**mem-an-tine** /memən,tēn/ ► **n.** a prescription drug for the treatment of Alzheimer's disease. It protects the brain's nerve cells against glutamate, which is released in excess by Alzheimer's-damaged brain cells. Also called **NAMENDA** (trademark).

**mem-ber** /mem'bər/ ► **n.** 1 an individual, thing, or organization belonging to a group: *a member of the drama club* | *interest from members of the public* | *a member of the Lily family* | [as modifier] *member countries of the Central African Customs Union.*

■ (also **Member**) a person formally elected to take part in the proceedings of certain organizations: *members of Congress* | *Member of Parliament.*

2 a constituent piece of a complex structure: *the main member that joins the front and rear axles.* ■ a part of a sentence, equation, group of figures, mathematical set, etc.

3 archaic a part or organ of the body, esp. a limb. ■ (also **male member**) the penis. Compare with **MEMBRUM VIRILE**.

— **DERIVATIVES** **mem-bered** **adj.** [In combination] (chiefly Chemistry) *a six-membered oxygen-containing ring.*

— **ORIGIN** Middle English: via Old French from Latin *membrum* 'limb.'

**mem-ber-ship** /mem'bər,ʃɪp/ ► **n.** the fact of being a member of a group: *I was selected for membership in the National Honor Society* | [as modifier] *a membership card.* ■ [in sing.] the number or body of members in a group: *our membership has grown by 600,000 in the past 18 months.*

**mem-brane** /mem,bræn/ ► **n.** Anatomy & Zoology a pliable sheetlike structure acting as a boundary, lining, or partition in an organism. ■ a thin pliable sheet or skin of various kinds: *the concrete should include a membrane to prevent water seepage.*

■ Biology a microscopic double layer of lipids and proteins that bounds cells and organelles and forms structures within cells.

— **DERIVATIVES** **mem-brana-ceous**

/membrə'nəʃəs/ **adj.**, **mem-brane-ous**

/membrə'nēs/ **adj.**, **mem-branous** /membrənəs, mem'brənəs/ **adj.**

— **ORIGIN** late Middle English: from Latin *membrana*, from *membrum* 'limb.'

**mem-branous lab-y-rinth** /membrənəs, mem'brənəs/ ► **n.** see **LABYRINTH**.

**mem-brum vir-ile** /membrəm 'vɪrāl, vɪ'rɪl/ ► **n.** archaic the penis.

— **ORIGIN** Latin, literally 'male member.'

**meme** /mēm/ ► **n.** an element of a culture or system of behavior that may be considered to be passed from one individual to another by nongenetic means, esp. imitation. ■ an image, video, phrase, etc. that is passed electronically from one Internet user to another.

— **DERIVATIVES** **me-met-ic** /mē'metɪk, mē-/ **adj.**

— **ORIGIN** 1970s: from Greek *mimēma* 'that which is imitated,' on the pattern of *gene*.

**WORD TRENDS** When the British scientist Richard Dawkins coined the word *meme* in his 1976 book *The Selfish Gene*, he wanted a word like *gene* that conveyed the way in which ideas and behavior spread within society by nongenetic means. Since then, the word has been picked up to describe a piece of information spread by e-mail or via blogs and social networking sites. A meme can be almost anything—a joke, a video clip, a cartoon, a news story—and can also evolve as it spreads, with users editing the content or adding comments. Common collocates in the Oxford English Corpus are *spread*, *pass*, and *transmit*: as with the Internet sense of **VIRAL**, *meme* uses the metaphor of disease and infection.

**Me-mel** /māməl/ 1 German name for **KLAIPEDA**. ■ a former district of East Prussia, centered on the city of Memel (Klaipeda).

2 the Neman River in its lower course (see **NEMAN**).

**me-men-to** /mə'men,tō/ ► **n.** (pl. **mementos** or **mementoes**) an object kept as a reminder or souvenir of a person or event: *you can purchase a memento of your visit.*

— **ORIGIN** late Middle English (denoting a prayer of commemoration): from Latin, literally 'remember!', imperative of *meminisse*.

**me-men-to mo-ri** /mə'men,tō 'mōrē/ ► **n.** (pl. **same**) an object serving as a warning or reminder of death, such as a skull.

— **ORIGIN** Latin, literally 'remember (that you have) to die.'

**mem-o** /memō/ ► **n.** (pl. **memos**) informal a written message, esp. in business.

— **ORIGIN** early 18th cent.: abbreviation of **MEMORANDUM**.

**mem-oir** /mem,wär, -wōr/ ► **n.** 1 a historical account or biography written from personal knowledge or special sources: *in 1924 she published a short memoir of her husband.* ■ **(memoirs)** an autobiography or a written account of one's memory of certain events or people.

2 an essay on a learned subject: *an important memoir on Carboniferous crustacea.* ■ **(memoirs)** the proceedings or transactions of a learned society: *Memoirs of the Horticultural Society.*

— **DERIVATIVES** **mem-oir-ist** /-ɪst/ **n.**

— **ORIGIN** late 15th cent. (denoting a memorandum or record): from French *mémoire* (masculine), a special use of *mémoire* (feminine) 'memory.'

**mem-o-ra-bil-i-a** /mem(ə)rə'bɪlə/ ► **plural n.** [treated as sing. or pl.] objects kept or collected because of their historical interest, esp. those associated with memorable people or events: *World Series memorabilia.* ■ archaic memorable or noteworthy things.

**PRONUNCIATION KEY** ə ago, up; ər over, fur; a hat; ā ate; ā car; e let; ē see; i fit; i by; NG sing; ō go; ō law, for; oi toy; ōō good; ōō goo; ou out; TH thin; TH then; ZH vision

## **EXHIBIT 8**

# **Dictionary of Mechanical Engineering**

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**G.H.F. Nayler**

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## Preface to First Edition

This dictionary has been compiled to cover the very large number of mechanical engineering terms in common use in a handy compact volume. The term “mechanical engineering” has been interpreted as mainly the production of, the means for, and the utilization of, mechanical power in engines, transport and mechanisms. It has also been borne in mind that tools, and the making of them, are of first importance, but in order to keep within certain limits those tools that are used by hand have been omitted, except for one or two rare exceptions.

As regards power, its production involves the design and construction of many types of device to enable energy to be developed from fundamental sources and then on to prime movers. As far as possible, terms likely to be found in other dictionaries of the series have been omitted, except where the application of a term is clearly common to more than one branch of engineering. Consequently, many fields allied to the mechanical engineering industry, such as foundry practice, metallurgy, metrology and welding, all of which are vital to the industry but are not in themselves mechanical, have been given only minor attention.

In preparing a work of this kind it is necessary to consult many sources, since the choice of clear and concise definitions is always a difficult task. The selection of terms has been based mainly on the reading of current literature, including the foremost engineering journals. Thus many well known but little used terms may not be found. Terms printed in bold italics in the text indicate entries that will provide the reader with additional information.

The illustrations are intended to help the less expert and are spread over the large field of mechanical engineering, while avoiding intricate subjects which are too complicated for simple line drawings.

The authors are much indebted to Miss E. E. Metcalfe for her valuable assistance in the preparation of the line drawings, and to the Publishers' staff\* for their helpful cooperation at all times during the passage of the dictionary through the press.

**J.L. and G.H.F. Naylor**

\*George Newnes Ltd., London

## **Preface to Fourth Edition**

The dictionary has been further updated and enlarged while retaining practically all of its original contents. With the recent advances in very small size mechanical engineering, micromachining and nanotechnology have been included. Nomenclature used in the manufacture of composites has also been added. Terms which have their main usage on the North American Continent now receive more prominence than previously. Cross-references have always been given full and careful attention and, where relevant, the reader is guided, as in a thesaurus, to a term of opposite meaning.

Clear understandable terminology is essential to efficient, accurate and comprehensive information distribution and retrieval. It is hoped that this edition will further the above aims worldwide in the field of mechanical engineering.



## Acknowledgments

I am pleased to record my gratitude to Don Goodsell for his advice and encouragement and for the use of four figures from his companion *Dictionary of Automotive Engineering*. I am also grateful to the staff of the Society of Automotive Engineers for their full support in the production of this edition, and Butterworth-Heinemann for co-publishing this work.

**Gordon H.F. Naylor**

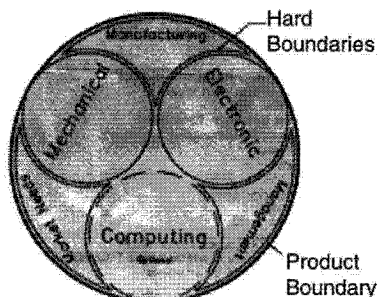


Figure M.8 Mechatronics.

**member** When considering the design of a mechanism or structure, a member is taken to be a single definable part, such as beam, plate or column, which can be easily analysed and stressed.

**mercurial compensated pendulum** See *pendulum*.

**mesh** (a) The state of gears when in contact. (See Figure B.10.) (b) The size of the openings in gratings, sieves, etc.

**meshed** A term implying that a *gear*, or system of gears, is ready for power to be transmitted through the gear.

**metal detector** An electrical instrument for detecting stray metal parts in non-metallic raw materials and finished parts. It usually gives visible and audible warnings, ejects the item or stops the production flow.

**metal limits** See *limits (metal)*.

**metal sawing machine** A machine used for sawing metal bars, tubes, etc., which are held in a *machine vice* while a reciprocating powered hacksaw cuts through them.

**metal spinning** The shaping of sheet-metal disc into circular or molded shapes on a lathe *face plate* by the application of lateral pressure. See *spinning*; Figure S.15.

**metal spraying (powder spraying)** The application of a metal surface by spraying molten metal from a gun, possibly with ionization. The coating metal may be supplied to a hot gun as a powder or a thin rod.

**metal spring coupling** Spring steel loops set in axial slots in a pair of adjacent *flanges* attached to two independent shafts. The couplings permit transmission of *torque* between the shafts, even if the coaxial alignment is poor.

**metal tolerance** See *tolerance*.

**metallic packing** See *packing*.

**meter, rotary piston** See *rotary piston meter*.



## **EXHIBIT 9**

Appln. No.: 14/103,324  
Amendment Dated March 7, 2016  
Reply to Office Action of December 7, 2015

TEVE-139US1

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

Appln. No: 14/103,324  
Applicant: Declan Walsh et al.  
Filed: December 11, 2013  
Title: DOSE COUNTERS FOR INHALERS, INHALERS AND  
METHODS OF ASSEMBLY THEREOF  
T.C./A.U.: 2876  
Examiner: Daniel A. Hess  
Confirmation No.: 3830  
Docket No.: TEVE-139US1

**AMENDMENT UNDER 37 C.F.R. § 1.116**

**Expedited Procedure**

Mail Stop AF  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Commissioner:

Responsive to the Final Office Action dated December 7, 2015, please amend the above-identified application as follows:

- ☐ **Amendments to the Specification** begin on page \_\_\_\_\_ of this paper.
- ☒ **Amendments to the Claims** are reflected in the listing of claims which begins on page 2 of this paper.
- ☐ **Amendments to the Drawings** begin on page \_\_\_\_\_ of this paper and include an attached replacement sheet(s).
- ☐ **Amendments to the Abstract** are on page \_\_\_\_\_ of this paper. A clean version of the Abstract is on page \_\_\_\_\_ of this paper.
- ☒ **Remarks/Arguments** begin on page 4 of this paper.

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**Amendments to the Claims:** This listing of claims will replace all prior versions and listings of claims in the application.

Listing of Claims:

1. (Currently Amended) An inhaler for metered dose inhalation, the inhaler comprising:  
  
a main body having a canister housing,  
  
a medicament canister, which is moveable relative to the canister housing and retained in a central outlet port of the canister housing arranged to mate with a canister fire stem of the medicament canister and movable relative thereto, and  
  
a dose counter, ~~the dose counter~~ having an actuation member having at least a portion thereof located in the canister housing for operation by movement of the medicament canister,  
  
wherein the canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall ~~and located directly adjacent the actuation member~~, and  
  
wherein the canister housing has a longitudinal axis X which passes through the center of the central outlet port,  
  
the inner wall canister support formation, the actuation member, and the central outlet port lying in a common plane coincident with the longitudinal axis X.
2. (Previously Presented) The inhaler as claimed in claim 1 wherein the medicament canister is movable relative to the dose counter.
3. (Original) The inhaler as claimed in claim 1 further comprising an aperture formed in the inner wall through which the portion of the actuation member extends.
4. (Original) The inhaler as claimed in claim 1, wherein the first inner wall canister support formation comprises a support rail which extends longitudinally along an inside surface of the main body.
5. (Original) The inhaler as claimed in claim 4, wherein the support rail includes a step formed thereon.

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6. (Original) The inhaler as claimed in claim 4 further comprising a plurality of support rails each of which extends longitudinally along an inside surface of the main body.
7. (Original) The inhaler as claimed in claim 6, wherein two of the plurality of support rails are positioned at opposite ends of the inside surface of the main body to face each other.
8. (Original) The inhaler as claimed in claim 4, wherein the support rail includes two steps formed thereon, the steps being spaced apart longitudinally along an inside surface of the main body.
9. (Original) The inhaler as claimed in claim 4, wherein the support rail merges with the inner wall at a location adjacent the aperture.
10. (Original) The inhaler as claimed in claim 9, wherein a width dimension of the support rail is not constant, and the width dimension is greatest at the location where the support rail merges with the inner wall.
11. - 20. (Cancelled)

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**Remarks/Arguments:**

**Claim Status**

Claims 1-10 are currently pending and stand rejected. Claim 1 has been amended and support for the amendments may be found, *for example*, in the original application at page 11, lines 21 to 27, and in FIGs. 7D and 9. No new matter has been added.

**Claim Rejections – 35 USC § 103**

Claims 1-10 are rejected under pre-AIA 35 U.S.C. § 103(a) as being unpatentable over Morton et al. (US 2005/0087191) in view of Davies et al. (US 2006/0107949). The Applicant respectfully requests reconsideration of this rejection for the reasons set forth hereinafter.

In establishing a prima facie case of obviousness, “all of the claim limitations must be considered.” M.P.E.P. §2143. Sole independent claim 1 recites features that are neither disclosed nor suggested by the cited references, namely:

An inhaler for metered dose inhalation, the inhaler comprising: a main body having a canister housing, a medicament canister, which is moveable relative to the canister housing and ***retained in a central outlet port of the canister housing arranged to mate with a canister fire stem of the medicament canister***, and a dose counter having an actuation member having at least a portion thereof located in the canister housing for operation by movement of the medicament canister,

wherein the canister housing has an inner wall, and a first inner wall canister support formation extending inwardly from a main surface of the inner wall, ***and***

***wherein the canister housing has a longitudinal axis X which passes through the center of the central outlet port,***

***the inner wall canister support formation, the actuation member, and the central outlet port lying in a common plane coincident with the longitudinal axis X.*** [Emphasis Added]

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By way of background to the instant invention recited in amended claim 1, the dash-dot line shown below depicts how the inner wall canister support formation 144, the actuation member at 74, and the central outlet port 148 lie in a common plane coincident with the longitudinal axis X at 148.

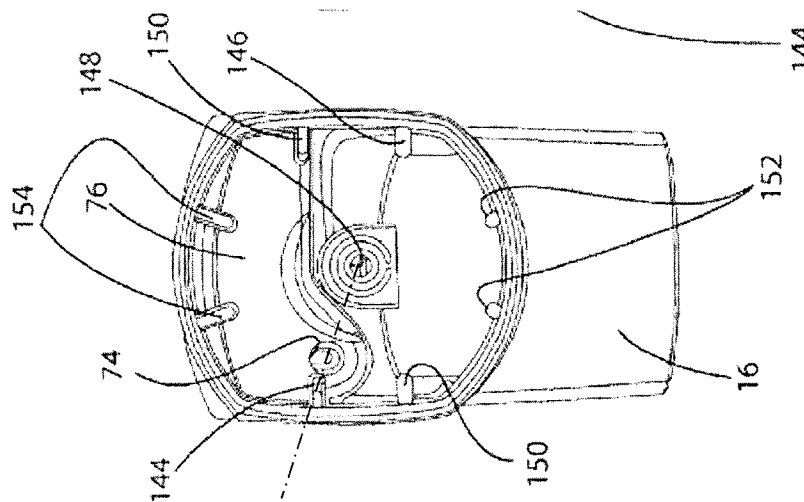


FIG. 7D

As explained in the instant application, this arrangement is "*highly advantageous in that the first inner wall canister support formation can prevent a canister from rocking too much relative to the main body of the inhaler. Since the canister may operate the actuation member of the dose counter, this substantially improves dose counting and avoids counter errors.*" Page 11, lines 16-20. Also, as set forth in the instant application, the claimed arrangement has the advantage of preventing the canister from rocking towards the position of the dose counter actuation member, which rocking can change the height of the actuation member and thereby undesirably alter the accuracy of the dose counter (see page 11, lines 25-27, and page 27 lines 23-28). It is worth noting that the magnitude of the rocking does not have to be great for it to have a potentially detrimental effect on counter performance. By way of illustration, on page 31, lines 14-15 of the present application, it is disclosed that the distance between the average start and average reset position of such counters may be about 0.7 mm.

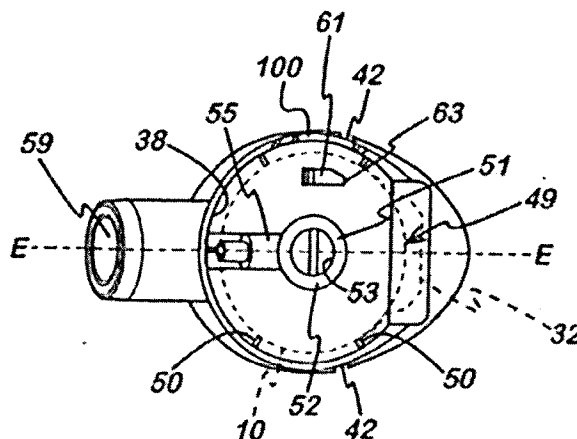


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Applicant has discovered that by minimising and/or eliminating the described rocking of the canister in the direction of the actuation member, by way of the specific positioning of a canister support formation relative to the actuator and outlet port, the present invention improves the accuracy of such dose counters. Neither the problem of canister rocking, nor the solution of the specific placement of the canister support formation are taught or suggested by the prior art, which is discussed below.

Turning now to Davies', it is clear that it is not possible to draw a straight line through the center of the stem block (53), the rib (50) and the actuator aperture (61) of FIG. 13 in Davies (below). Accordingly, Davies' inner wall canister support formation, actuation member, and outlet port do not lie in a common plane coincident with the longitudinal axis (near 53). Accordingly, Davies' neither discloses all of the features recited in amended claim 1, nor does Davies' device confer the same benefits as the device that is recited in amended claim 1.



Morton does not disclose the above-identified features of amended claim 1, and the Office Action does not present any arguments to the contrary. Thus, amended claim 1 is not obvious in view of the cited art.

Lastly, the Applicant notes that the Office Action has made the general observation that *"having a gap in the canister housing that is filled by support rails is not functionally better or worse than having a canister housing with less of a gap, more closely conforming to the shape of the housing and obviating the need for the types of rails in the instant invention."* The Applicant disagrees with this statement. Simply conforming the housing to the shape of the canister would increase the airflow resistance of the inhaler and could affect the ability of users with reduced lung function (e.g., the elderly, young or those suffering from an asthma or COPD

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exacerbation) to draw air through the inhaler and inhale medicament effectively. Accordingly, using a body with a greater clearance and accompanying support ribs provides increased design flexibility and a tangible benefit over the approach set forth in the Office Action.

Accordingly, because claim 1 includes features that are neither disclosed nor suggested by the cited references, *prima facie* obviousness cannot be established based on the cited references. The dependent claims that stand rejected should also be allowed at least as being dependent upon an allowable base claim. Reconsideration of claims 1-10 is respectfully requested.

### **Conclusion**

In view of the remarks set forth above, the Applicant respectfully submits that this application is now in condition for allowance, which action is respectfully requested. If the Examiner believes an interview will advance the prosecution of this application, it is respectfully requested that the Examiner contact the undersigned to arrange the same.

Respectfully submitted,

/Brett J. Rosen/

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Brett J. Rosen, Reg. No. 56,047  
Attorney for Applicants

BJR/mf

Dated: March 7, 2016

P.O. Box 980  
Valley Forge, PA 19482  
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The Director is hereby authorized to charge or credit Deposit Account No. **18-0350** for any additional fees, or any underpayment or credit for overpayment in connection herewith.

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## **EXHIBIT 10**

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**ac-ti-vate** \ak-tə-vāt\ *vb* -vat-ed; -vat-ing *vt* (1626): to make active or more active: as **a** (1): to make (as molecules) reactive or more reactive **(2)**: to convert (as a provitamin) into a biologically active derivative **b**: to make (a substance) radioactive **c**: to treat (as carbon or alumina) so as to improve adsorptive properties **d** (1): to set up or formally institute (as a military unit) with the necessary personnel and equipment **(2)**: to put (an individual or unit) on active duty **~ vi**: to become active — **ac-ti-va-tion** \ak-tə-vā-shən\ *n* — **ac-ti-va-tor** \ak-tə-vā-tər\ *n*

**activated carbon** *n* (1921): a highly adsorbent powdered or granular carbon made usu. by carbonization and chemical activation and used chiefly for purifying by adsorption — called also *activated charcoal*

**activation analysis** *n* (1949): NEUTRON ACTIVATION ANALYSIS

**activation energy** *n* (1940): the minimum amount of energy required to convert a normal stable molecule into a reactive molecule

**ac-tive** \ak-tiv\ *adj* [ME, fr. AF or L; AF *actif*, fr. L *activus*, fr. *actus*, pp. of *agere* to drive, do — more at AGENT] (14c) **1**: characterized by action rather than by contemplation or speculation (an ~ life) **2**: producing or involving action or movement **3 a** of a verb form or voice: asserting that the person or thing represented by the grammatical subject performs the action represented by the verb (hits in "he hits the ball" is ~) **b**: expressing action as distinct from mere existence or state **4**: quick in physical movement: LIVELY **5**: marked by vigorous activity: BUSY (the stock market was ~) **6**: requiring vigorous action or exertion (sports) **7**: having practical operation or results: EFFECTIVE (an ~ law) **8 a**: disposed to action: ENERGETIC (took an ~ interest) **b**: engaged in an action or activity (an ~ club member) **c** of a volcano: currently erupting or likely to erupt — compare DORMANT **2a**, EXTINCT **1b** **d**: characterized by emission of large amounts of electromagnetic energy (an ~ galactic nucleus) **9**: engaged in full-time service esp. in the armed forces (duty) **10**: marked by present operation, transaction, movement, or use (an ~ account) **11 a**: capable of acting or reacting: reacting readily (nitrogen) (ingredients) **b**: tending to progress or to cause degeneration (tuberculosis) **c** of an electronic circuit element: capable of controlling voltages or currents **d** (1): requiring the expenditure of energy (calcium ion uptake) **(2)**: functioning by the emission of radiant energy or sound (radar is an ~ sensor) **12**: still eligible to win the pot in poker **13**: moving down the line: visiting in the set — used of couples in contradances or square dances — **active** *n* — **active-ly** *adv* — **ac-tive-ness** *n*

**active immunity** *n* (1897): usu. long-lasting immunity that is acquired through production of antibodies within the organism in response to the presence of antigens — compare PASSIVE IMMUNITY

**ac-tive-ma-trix** \ak-tiv-mā-triks\ *adj* (1980): of, relating to, or being an LCD in which each pixel is individually controlled

**active site** *n* (1957): a region on the surface of an enzyme whose shape permits binding only of a specific molecular substrate that then undergoes catalysis

**active transport** *n* (1963): the movement of a chemical substance by the expenditure of energy against a gradient in concentration or in electrical potential across a plasma membrane

**ac-tive-wear** \ak-tiv-wēr\ *n* (1978): SPORTSWEAR

**ac-tiv-ism** \ak-tiv-vi-zəm\ *n* (1915): a doctrine or practice that emphasizes direct vigorous action esp. in support of or opposition to one side of a controversial issue — **ac-tiv-ist** \-vist\ *n* or *adj* — **ac-tiv-is-tic** \ak-ti-vi-s-tik\ *adj*

**ac-tiv-i-ty** \ak-ti-vā-tē\ *n*, *pl* -ties (1530) **1**: the quality or state of being active **2**: vigorous or energetic action: LIVELINESS **3**: natural or normal function: as **a**: a process (as digestion) that an organism carries on or participates in by virtue of being alive **b**: a similar process actually or potentially involving mental function: *specif*: an educational procedure designed to stimulate learning by firsthand experience **4**: an active force **5 a**: a pursuit in which a person is active **b**: a form of organized, supervised, often extracurricular recreation **6**: an organizational unit for performing a specific function; also: its function or duties

**act of God** (1783): an extraordinary interruption by a natural cause (as a flood or earthquake) of the usual course of events that experience, prescience, or care cannot reasonably foresee or prevent

**ac-to-my-o-sin** \ak-tə-mi-ō-sən\ *n* [ISV *actin* + *-o-* + *myosin*] (1942): a contractile complex of actin and myosin that together with ATP is active during muscular contraction

**ac-tor** \ak-tər\ *also* -tər\ *n* (15c) **1**: one that acts: DOER **2 a**: one who represents a character in a dramatic production **b**: a theatrical performer **c**: one who behaves as if acting a part **3**: one that takes part in any affair — **ac-tor-ish** \-tə-rish\ *adj* — **ac-tor-ly** \-tər-lē\ *adj*

**act out** *vt* (1611) **1 a**: to represent in action (children act out what they read) **b**: to translate into action (unwilling to act out their beliefs) **2**: to express (as an impulse or a fantasy) directly in overt behavior without modification to comply with social norms **~ vi**: to behave badly or in a socially unacceptable often self-defeating manner esp. as a means of venting painful emotions (as fear or frustration)

**ac-tress** \ak-trəs\ *n* (1668): a woman who is an actor — **ac-tress-ly** \-trə-sē\ *adj*

**Acts** \akts\ *n* *pl* *but sing in constr* (1539): a book in the New Testament narrating the beginnings of the Christian church — called also *Acts of the Apostles*; see BIBLE table

**ac-tu-al** \ak-ch(ə-w)əl, -sh(ə-w)əl; -chū-əl, -shū-əl\ *adj* [ME *actual*, fr. LL *actualis*, fr. L *actus* act] (14c) **1 obs**: ACTIVE **2 a**: existing in act and not merely potentially **b**: existing in fact or reality (an ~ and imagined conditions) **c**: not false or apparent (costs) **3**: existing or occurring at the time: CURRENT (caught in the ~ commission of a crime)

**actual cash value** *n* (ca. 1946): money equal to the cost of replacing lost, stolen, or damaged property after depreciation

**ac-tu-al-i-ty** \ak-chə-wā-lā-tē, -shə-shə\ *n*, *pl* -ties (1618) **1**: the quality or state of being actual **2**: something that is actual: FACT, REALITY (possible risks which have been seized upon as actualities — T. S. Eliot) — **in actuality**: in actual fact

**ac-tu-al-ize** \ak-ch(ə-w)ə-līz, -sh(ə-w)ə-līz\ *vb* -ized; -iz-ing *vt* (1701): to make actual: REALIZE **~ vi**: to become actual — **ac-tu-al-i-za-tion** \ak-ch(ə-w)ə-lā-zā-shən, -sh(ə-w)ə-lā-zən\ *n*

**ac-tu-al-ly** \ak-ch(ə-w)ə-lē, -sh(ə-w)ə-lē; 'aksh-lē, 'aks-əl\ *adv* (15c) **1**: in act or in fact: REALLY (nominally but not ~ independent — Karl Loewenstein) (won't ~ arrive for an hour) **2**: in point of fact — used to suggest something unexpected (he could ~ read the Greek)

**ac-tu-ar-i-al** \ak-chə-wēr-ē-əl, -wēr-rē-, -shə-\ *adj* (1869) **1**: of or relating to actuaries **2**: relating to statistical calculation esp. of life expectancy — **ac-tu-ar-i-al-ly** \-ē-ə-lē\ *adv*

**ac-tu-ary** \ak-chə-wēr-ē-, -shə-, -wēr-rē-\ *n*, *pl* -aries [L *actuarius* shorthand writer, alter. of *actarius*, fr. *actum* record — more at ACT] (1553) **1 obs**: CLERK, REGISTRAR **2**: a person who calculates insurance and annuity premiums, reserves, and dividends

**ac-tu-ate** \ak-chə-wāt, -shə-\ *vt* -at-ed; -at-ing [ML *actuatus*, pp. of *actuare* to execute, fr. L *actus* act] (1645) **1**: to put into mechanical action or motion **2**: to move to action *syn* see MOVE — **ac-tu-a-tion** \ak-chə-wā-shən, -shə-\ *n*

**ac-tu-a-tor** \ak-chə-wā-tər, -shə-\ *n* (1856): one that actuates; *specif*: a mechanical device for moving or controlling something

**act up** *vi* (1903) **1**: to act in a way different from that which is normal or expected: as **a**: to behave in an unruly, recalcitrant, or capricious manner (the children were acting up) **b**: SHOW OFF **c**: to function improperly (this typewriter is acting up again) **2**: to become active or acute after being quiescent (her rheumatism started to act up)

**ACT UP** *abbr* AIDS Coalition to Unleash Power

**ac-tu-ity** \ə-kyū-ə-tē, ə-\ *n*, *pl* -ities [ME *acuite* acidity, fr. MF *acuité*, fr. ML *acuitat-*, *acuitas*, fr. L *acuere*] (1543): keenness of perception: SHARPNESS

**acule-ate** \ə-kyū-lē-ət\ *adj* [L *aculeatus* having stings, fr. *aculeus* sting, fr. *acus*] (1875): relating to or being hymenopterans (as bees, ants, and many wasps) of a division (Aculeata) typically having the ovipositor modified into a stinger

**acu-men** \ə-kyū-mən, 'a-kyə-mən\ *n* [L *acumin-*, *acumen*, lit., point, fr. *acuere*] (ca. 1579): keenness and depth of perception, discernment, or discrimination esp. in practical matters *syn* see DISCERNMENT

**acu-mi-nate** \ə-kyū-mə-nāt\ *adj* (1646): tapering to a slender point

**acu-pres-sure** \ə-kyə-pre-shər, 'a-kə-\ *n* (1958): the application of pressure (as with the thumbs or fingertips) to the same discrete points on the body stimulated in acupuncture that is used for its therapeutic effects (as the relief of tension or pain) — compare SHIATSU

**acu-punc-ture** \-pən(k)-chər\ *n* [L *acus* + E *puncture*] (1684): an orig. Chinese practice of inserting fine needles through the skin at specific points esp. to cure disease or relieve pain (as in surgery) — **acupunc-ture** *vt* — **acu-punc-tur-ist** \-pən(k)-chə-ris-t\ *n*

**acute** \ə-kyūt\ *adj* **acut-er**; **acut-est** [ME, fr. L *acutus*, pp. of *acuere* to sharpen, fr. *acus* needle; akin to L *acer* sharp — more at EDGE] (14c)

**1 a** (1): characterized by sharpness or severity (pain) **(2)**: having a sudden onset, sharp rise, and short course (disease) **(3)**: being, providing, or requiring short-term medical care (as for serious illness or traumatic injury) (hospitals) (an ~ patient) **b**: lasting a short time (experiments) **2**: ending in a sharp point: as **a**: being or forming an angle measuring less than 90 degrees (an ~ angle) **b**: composed of acute angles (an ~ triangle) **3 a** of an accent mark: having the form **b**: marked with an acute accent **c**: of the variety indicated by an acute accent **4 a**: marked by keen discernment or intellectual perception esp. of subtle distinctions: PENETRATING (an ~ thinker) **b**: responsive to slight impressions or stimuli (hearing) **5**: felt, perceived, or experienced intensely (distress) **6**: seriously demanding urgent attention (an ~ emergency) — **acute-ly** *adv* — **acute-ness** *n*

*syn* ACUTE, CRITICAL, CRUCIAL mean of uncertain outcome. ACUTE stresses intensification of conditions leading to a culmination or breaking point (an acute housing shortage). CRITICAL adds to ACUTE implications of imminent change, of attendant suspense, and of decisiveness in the outcome (the war has entered a critical phase). CRUCIAL suggests a dividing of the ways and often a test or trial involving the determination of a future course or direction (a crucial vote). *syn* see in addition SHARP

**ACV** *abbr* 1 actual cash value 2 air-cushion vehicle

**acy-clic** \ə-si-klīk, -sī-\ *adj* (1875): not cyclic: as **a**: not disposed in whorls or cycles **b**: having an open-chain structure: ALIPHATIC (an ~ compound)

**acy-clo-vir** \ə-si-klō-vīr\ *n* [Fr. + *cycl-* + *virus*] (1979): a cyclic synthetic nucleoside C<sub>8</sub>H<sub>11</sub>N<sub>5</sub>O<sub>3</sub> used esp. to treat the symptoms of chicken pox, shingles, and the genital form of herpes simplex

**ac-yl** \ə-səl\ *n*, *often attrib* [ISV, fr. *acid*] (1899): a radical RCO- derived usu. from an organic acid by removal of the hydroxyl from all acid groups — often used in combination

**ac-yl-ate** \ə-sə-lāt\ *vt* -at-ed; -at-ing (1907): to introduce an acyl radical into — **ac-yl-a-tion** \ə-sə-lā-shən\ *n*

**1 ad** \əd\ *n*, *often attrib* (1841) **1**: ADVERTISEMENT **2**: ADVERTISING

**2 ad** *n* (1947): ADVANTAGE **4**

**AD** *abbr* 1 active duty 2 after date 3 Alzheimer's disease 4 anno Domini — often printed in small capitals and often punctuated 5 assembly district 6 assistant director 7 athletic director

**AD** *abbr* analog/digital

**ad-** or **ac-** or **af-** or **ag-** or **al-** or **ap-** or **as-** or **at-** *prefix* [ME, fr. AF & L; AF, fr. L, fr. *ad* — more at AT] **1**: to: toward — usu. *ac-* before *c*, *k*, or *q* (acculturation) and *af-* before *f* (affluent) and *ag-* before *g* (aggradation) and *al-* before *l* (alliteration) and *ap-* before *p* (apportion) and *as-* before *s* (assuasive) and *at-* before *t* (attune) and *ad-* before other sounds but sometimes *ad-* even before one of the listed consonants (adsorb) **2**: near: adjacent to — in this sense always in the form *ad-* (adrenal)

**1 ad** *adv* *suffix* [L *ad*] in the direction of: toward (cephalad)

**2 ad** *n* *suffix* [prob. fr. NL *ad-*, *-as*, fr. Gk. suffix denoting descent from or connection with]: member of a botanical group (bromeliad)

\ə\ abut \ə\ kitten, F table \ər\ further \ə\ ash \ə\ ace \ə\ mop, mar \ə\ out \ch\ chin \e\ bet \ē\ easy \g\ go \h\ hit \i\ ice \j\ job \ŋ\ sing \ō\ go \ō\ law \ōi\ boy \th\ thin \th\ the \ū\ loot \ū\ foot \y\ yet \zh\ vision, beige \k, ʔ, æ, ɪ, ʊ, ɪ, see Guide to Pronunciation



**any-ways** \-wāz\ *adv* (13c) **1 a** *archaic*: ANYWISE **b** *dial*: to any degree at all **2** *chiefly dial*: ANYHOW, ANYWAY  
**any-where** \-h(w)er-, (h)wēr\ *adv* (14c) **1**: at, in, or to any place or point **2**: to any extent: AT ALL (we're not ~ near to being finished)  
**3** — used as a function word to indicate limits of variation (<~ from 40 to 60 students>)  
**anywhere** *n* (1924): any place  
**any-where's** \-h(w)erz-, (h)wērz\ *adv* (1775) *chiefly dial*: ANYWHERE  
**any-wise** \-e-nē-, wīz\ *adv* (13c): in any way whatever: AT ALL  
**An-zac** \an-'zak\ *n* [Australian and New Zealand Army Corps] (1915): a soldier from Australia or New Zealand  
**AO** *abbr* **1** account of **2** and others  
**A-OK** \ā-(j)ō-'kā\ *adv* or *adj* (1961): very definitely OK  
**A1** \ā-'wān\ *adj* (1837) **1**: having the highest possible classification — used of a ship **2**: of the finest quality: FIRST-RATE  
**A/1C** *abbr* airman first class  
**aor** *abbr* aorist  
**aor-ist** \ā-'a-rast\ *n* [LL & Gk; LL *aoristos*, fr. Gk, fr. *aoristos* undefined, fr. *a* + *horistos* definable, fr. *horizein* to define — more at HORIZON] (1581): an inflectional form of a verb typically denoting simple occurrence of an action without reference to its completeness, duration, or repetition — **aorist** or **aor-istic** \ā-'a-ris-tik\ *adj* — **aor-ist-i-cal-ly** \-ti-k(-)lē\ *adv*  
**aor-ta** \ā-'ōr-tā\ *n*, *pl* -tas or -tae \-tē\ [NL, fr. Gk *aortē*, fr. *aelein* to lift] (1543): the great arterial trunk that carries blood from the heart to be distributed by branch arteries through the body — see HEART illustration — **aor-tic** \-ōr-tik\ *adj*  
**aortic arch** *n* (1868): one of the arterial branches in vertebrate embryos that exist in a series of pairs with one on each side of the embryo, connect the ventral arterial system lying anterior to the heart to the dorsal arterial system above the alimentary tract, and persist in adult fishes but are reduced or much modified in the adult of higher forms  
**aor-tog-ra-phy** \ā-'ōr-'tā-grā-fē\ *n* (ca. 1935): arteriography of the aorta — **aor-to-graph-ic** \ā-'ōr-'tā-grā-fik\ *adj*  
**ao-u-dad** \ā-'ū-'dad-, ā-'ū-\ *n* [F, fr. Berber *audad*] (1861): a wild bovine (*Ammotragus lervia*) of No. Africa that is closely related to goats and sheep and has been introduced into the southwestern U.S. — called also *oudad* sheep, *Barbary sheep*  
**à ou-trance** \ā-'ū-'trāns\ *adv* [F] (1883): to the limit: UNSPARINGLY  
**ap** *abbr* **1** apostle **2** apothecaries  
**AP** *abbr* **1** additional premium **2** adjective phrase **3** airplane **4** American plan **5** antipersonnel **6** arithmetic progression **7** armor-piercing **8** Associated Press **9** author's proof  
**ap-** — see AD-  
**apo-** — see APO-  
**apace** \ā-'pās\ *adv* [ME, prob. fr. MF *à pas* on step] (14c) **1**: at a quick pace: SWIFTLY (growing ~) **2**: ABBREAST — used with *of* or *with* (trying to keep ~ with changes in technology)  
**Apache** \ā-'pa-čē-, in sense **3** ā-'pash\ *n*, *pl* **Apache** or **Apach-es** \-pā-čēz-, -pash-, -pa-shāz\ [AmerSp, perh. fr. Zuni *apachi* Navajo, Apachean] (1745) **1**: a member of a group of American Indian peoples of the southwestern U.S. **2**: any of the Athabascan languages of the Apache people **3** not cap [F, fr. *Apache* Apache Indian] **a**: a member of a gang of criminals esp. in Paris **b**: RUFFIAN — **Apach-e-an** \ā-'pa-čē-an\ *adj* or *n*  
**apana-ge** *var* of APPANAGE  
**ap-a-re-jo** \ā-'pā-'rā-(j)hō\ *n*, *pl* -jos [AmerSp] (1834): a packsaddle of stuffed leather or canvas  
**apart** \ā-'pārt\ *adv* [ME, fr. AF *a part*, lit., to one side] (14c) **1 a**: at a little distance (tried to keep ~ from the family squabbles) **b**: away from one another in space or time (towns 20 miles ~) **2 a**: as a separate unit: INDEPENDENTLY (viewed ~, his arguments were unsound) **b**: so as to separate one from another (found it hard to tell the twins ~) **3**: excluded from consideration: ASIDE (a few blemishes ~, the novel is excellent) **4**: in or into two or more parts: to pieces (coming ~ at the seams)  
**2 apart** *adj* (1728) **1**: SEPARATE, ISOLATED (those athletes are a breed ~) **2**: holding different opinions: DIVIDED — **apart-ness** *n*  
**apart from prep** (1833): other than: BESIDES, EXCEPT FOR  
**apart-heid** \ā-'pārt-'hīd-, -hīt\ *n* [Afrik, fr. *apart* apart + *-heid* -hood] (1947) **1**: racial segregation; *specific*: a former policy of segregation and political and economic discrimination against non-European groups in the Republic of So. Africa **2**: SEPARATION, SEGREGATION (cultural ~) (gender ~)  
**apart-ment** \ā-'pārt-'ment\ *n* [F *appartement*, fr. It *appartamento*] (1641) **1**: a room or set of rooms fitted esp. with housekeeping facilities and usu. leased as a dwelling **2**: a building containing several individual apartments — **apart-men-tal** \ā-'pārt-'men-tl\ *adj*  
**apartment building** *n* (1883): a building containing separate residential apartments — called also *apartment house*  
**apartment hotel** *n* (1909): a hotel containing apartments as well as accommodations for transients  
**ap-a-thet-ic** \ā-'pā-'thet-ik\ *adj* (1744) **1**: having or showing little or no feeling or emotion: SPIRITLESS **2**: having little or no interest or concern: INDIFFERENT *syn* see IMPASSIVE — **ap-a-thet-i-cal-ly** \-ti-k(-)lē\ *adv*  
**ap-a-ty** \ā-'pā-'thē\ *n* [Gk *apatheia*, fr. *apatēs* without feeling, fr. *a-* + *pathos* emotion — more at PATHOS] (1594) **1**: lack of feeling or emotion: IMPASSIVENESS **2**: lack of interest or concern: INDIFFERENCE  
**ap-a-tite** \ā-'pā-'tīt\ *n* [G *Apatit*, fr. Gk *apatē* deceit] (1803): any of a group of calcium phosphate minerals occurring in various colors as hexagonal crystals, as granular masses, or in fine-grained masses as the chief constituent of phosphate rock and of bones and teeth; *esp*: calcium phosphate fluoride  
**apato-sau-rus** \ā-'pā-'tā-'sōr-'as\ *n* [NL, fr. Gk *apatē* + *sauros* lizard] (ca. 1899): BRONTOSAURUS  
**APB** *abbr* all points bulletin  
**APB** \ā-'pē-'sē\ *n* [armored personnel carrier] (1966): an armored vehicle used to transport military personnel  
**ape** \āp\ *n* [ME, fr. OE *apa*; akin to OHG *affo* ape] (bef. 12c) **1 a**: MONKEY; *esp*: one of the larger tailless or short-tailed Old World forms **b**: any of two families (Pongidae and Hylobatidae) of large tailless simiiform primates (as the chimpanzee, gorilla, orangutan, or

gibbon) — called also *anthropoid*, *anthropoid ape* **2 a**: MIMIC **b**: a large uncouth person — **ape-like** \āp-'lik\ *adj*  
**ape vt** **aped**; **ap-ing** (1632): to copy closely but often clumsily and ineptly *syn* see COPY — **ap-er** *n*  
**ape** *adj* (ca. 1955): CRAZY, WILD — usu. used in the phrase *go ape*  
**apeak** \ā-'pēk\ *adj* or *adv* [alter. of earlier *apike*, prob. fr. F *à pic* vertically] (1596): being in a vertical position (with oars ~)  
**ape-man** \āp-'man-, 'man\ *n* (1873): a primate (as an australopithecine) intermediate in character between Homo sapiens and the higher apes  
**aper-çu** \ā-'per-'sü-, ā-'pār-'sü\ *n*, *pl* **aperçus** \-sü(z), -'süz\ [F, fr. *aperçu*, pp. of *apercevoir* to perceive, fr. OF *apercevoir*, fr. *a-* (fr. L *ad-*) + *percevere* to perceive — more at PERCEIVE] (1828) **1**: a brief survey or sketch: OUTLINE **2**: an immediate impression; *esp*: INSIGHT  
**ape-ri-ent** \ā-'pīr-'ē-ant\ *adj* [L *aperient*, *aperiens*, pp. of *aperire*] (1894): gently moving the bowels: LAXATIVE — **aperient** *n*  
**ape-ri-od-ic** \ā-'pīr-'ē-'ā-dik\ *adj* (1879) **1**: of irregular occurrence: not periodic (<~ floods> **2**: not having periodic vibrations: not oscillatory — **ape-ri-od-i-cal-ly** \-di-k(-)lē\ *adv* — **ape-ri-od-i-ci-ty** \-ē-'ā-'di-si-tē\ *n*  
**aper-i-tif** \ā-'per-'ā-'tif-, ā-'pār-(ā-)tif\ *n* [F *apéritif* aperient, aperitif, fr. MF *aperitif*, *adj.*, aperient, fr. ML *aperitivus*, irreg. fr. L *aperire*] (1894): an alcoholic drink taken before a meal as an appetizer  
**ap-er-ture** \āp-'ə(r)-chūr-, -char-, -tyūr-, -tūr\ *n* [ME, fr. L *apertura*, fr. *aperitus*, pp. of *aperire* to open] (15c) **1**: an opening or open space: HOLE **2 a**: the opening in a photographic lens that admits the light **b**: the diameter of the stop in an optical system that determines the diameter of the bundle of rays traversing the instrument **c**: the diameter of the objective lens or mirror of a telescope  
**apet-al-ous** \ā-'pē-'tāl-'əs\ *adj* (ca. 1706): having no petals  
**apex** \ā-'pek-s\ *n*, *pl* **apex-es** or **api-ces** \ā-'pā-'sēz-, 'a-\ [L] (1601) **1 a**: the uppermost point: VERTEX (the ~ of a mountain) **b**: the narrowed or pointed end: TIP (the ~ of the tongue) **2**: the highest or culminating point (the ~ of his career) *syn* see SUMMIT  
**Ap-gar score** \āp-'gār-\ *n* [Virginia Apgar †1974 Am. anesthesiologist] (1962): an index used to evaluate the condition of a newborn infant based on a rating of 0, 1, or 2 for each of the five characteristics of color, heart rate, response to stimulation of the sole of the foot, muscle tone, and respiration with 10 being a perfect score  
**aphae-re-sis** \ā-'fer-'ē-'sēs\ *n*, *pl* -ses \-sēz\ [LL, fr. Gk *aphaeresis*, lit., taking off, fr. *aphairein* to take away, fr. *apo-* + *hairein* to take] (ca. 1550): the loss of one or more sounds or letters at the beginning of a word (as in *round* for *around* and *coon* for *raccoon*) — **aph-ae-ret-ic** \ā-'fa-'re-tik\ *adj*  
**apha-sia** \ā-'fā-'zh(-)ə\ *n* [NL, fr. Gk, fr. *a-* + *-phasia*] (1867): loss or impairment of the power to use or comprehend words usu. resulting from brain damage — **apha-sic** \-zik\ *n* or *adj*  
**aphel-ion** \ā-'fēl-'yən-, ā-'hēl-\ *n*, *pl* -elia \-ya\ [NL, fr. *apo-* + Gk *hēlios* sun — more at SOLAR] (1656): the point in the path of a celestial body (as a planet) that is farthest from the sun — compare PERHELION  
**aphe-re-sis** \ā-'fē-'rē-'sēs\ *n*, *pl* -ses \-sēz\ [fr. *-apheresis* (as in *plasmapheresis*)] (1977): withdrawal of blood from a donor's body, removal of one or more blood components (as plasma, platelets, or white blood cells), and transfusion of the remaining blood back into the donor — called also *pheresis*  
**aphe-sis** \ā-'fā-'sēs\ *n*, *pl* -ses \-sēz\ [NL, fr. Gk, release, fr. *aphenai* to let go, fr. *apo-* + *hēnai* to send — more at JET] (1880): *aphaeresis* consisting of the loss of a short unaccented vowel (as in *lone* for *alone*) — **aphe-tic** \ā-'fē-'tik\ *adj* — **aphe-ti-cal-ly** \-ti-k(-)lē\ *adv*  
**aphid** \ā-'fād also 'a-fād\ *n* (1861): any of numerous very small soft-bodied homopterous insects (superfamily Aphidoidea) that suck the juices of plants  
**aphid lion** *n* (1949): any of several insect larvae (as a lacewing or ladybug larva) that feed on aphids — called also *aphis lion*  
**aphis** \ā-'fās also 'a-fās\ *n*, *pl* **aphi-des** \ā-'fā-'dēz-, 'a-fā-\ [NL *Aphid*, *Aphis*, genus name] (1771): any of a genus (*Aphis*) of aphids; broadly: APHID  
**apho-nia** \ā-'fō-'nē-\ *n* [NL, fr. Gk *aphōnia*, fr. *aphōnos* voiceless, fr. *a-* + *phōnē* sound — more at BAN] (1778): loss of voice and of all but whispered speech — **apho-nic** \-fā-'nik-, 'fō-\ *adj*  
**apho-rism** \ā-'fā-'rī-zəm\ *n* [MF *aphorisme*, fr. LL *aphorismus*, fr. Gk *aphorismos* definition, aphorism, fr. *aphorizein* to define, fr. *apo-* + *horizein* to bound — more at HORIZON] (1528) **1**: a concise statement of a principle **2**: a terse formulation of a truth or sentiment: ADAGE — **aph-o-ris-t** \-rīst\ *n* — **aph-o-ris-tic** \ā-'fā-'rīs-tik\ *adj* — **aph-o-ris-ti-cal-ly** \-ti-k(-)lē\ *adv*  
**aph-o-rize** \ā-'fā-'rīz\ *vi* -rized; -riz-ing (1669): to write or speak in or as if in aphorisms  
**apho-tic** \ā-'fō-'tik\ *adj* (ca. 1900): being the deep zone of an ocean or lake receiving too little light to permit photosynthesis  
**aph-ro-di-si-ac** \ā-'frā-'dē-'zē-, -ak-, -'dī-'zē-\ *n* [Gk *aphrodisiakos* sexual, gem with aphrodisiac properties, fr. *aphrodisia* heterosexual pleasures, fr. neut. pl. of *aphrodisios* of Aphrodite, fr. *Aphrodite*] (1719) **1**: an agent (as a food or drug) that arouses or is held to arouse sexual desire **2**: something that excites — **aphrodisiac** also **aph-ro-di-si-a-cal** \ā-'frā-'dī-'sī-'ā-'kal-, -'zī-\ *adj*  
**Aph-ro-di-te** \ā-'frā-'dī-'tē\ *n* [Gk *Aphrodite*] (1565): the Greek goddess of love and beauty — compare VENUS  
**api-a-ri-an** \ā-'pē-'er-'ē-an\ *adj* (1801): of or relating to beekeeping or bees  
**api-a-ris-t** \ā-'pē-'ā-'rist-, -pē-, -er-'ist\ *n* (1816): BEEKEEPER  
**api-ary** \ā-'pē-'er-, -e-'rē\ *n*, *pl* -aries [L *apiarium*, fr. *apis* bee] (1654): a place where bees are kept; *esp*: a collection of hives or colonies of bees kept for their honey  
**api-cal** \ā-'pī-'kal also 'a-pī-\ *adj* [prob. fr. NL *apicalis*, fr. L *apic-*, *apex*] (1828) **1**: of, relating to, or situated at an apex **2**: of, relating to, or

\ā\ about \ā\ kitten, F table \ār\ further \ā\ ash \ā\ ace \ā\ mop, mar  
\ā\ out \ā\ chin \ā\ bet \ā\ easy \ā\ go \ā\ hit \ā\ ice \ā\ job  
\ā\ sing \ā\ go \ā\ law \ā\ boy \ā\ thin \ā\ the \ā\ foot \ā\ foot  
\ā\ yet \ā\ vision, beige \ā\ 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000